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THE IMPROVED FINANCIAL CONDITION OF WATER WORKS IN THE UNITED STATES[1]

BY LEONARD METCALF[2]

Data have been submitted to this Association at previous conventions to show the effect upon the expenses and net revenues of water works in the United States, of the higher costs and lesser efficiencies resulting from war conditions. The first report was presented in 1918 under the title, "War Burdens of Water Works in the United States," and extensions of the data to cover later periods were submitted in 1919 and 1920. The present paper extends the data to include the records of the years 1920 and 1921, the figures having been furnished, as in previous cases, through the courtesy of the managers of the plants covered by the reports.

The data submitted herein for the years 1920 and 1921 do not cover precisely the same plants, but they are practically the same to all intents and purposes. The records of about forty-five plants, both publicly and privately owned, are included in the present tabulation, serving a gross population of 9,000,000 in the year 1920, as compared with about fifty plants, serving approximately the same total population, covered by the earlier reports.

[1] Presented before the Philadelphia Convention, May 17, 1922.

[2] Metcalf and Eddy, Consulting Engineers, Boston, Massachusetts.

The records indicate that, speaking in general terms, the water works of the country are past the period of acute distress due to the war, and that their revenues available for depreciation, interest, dividends and surplus, are approaching what would have constituted a normal basis *under pre-war conditions*, but they have not yet reached the higher level corresponding to post-war conditions, nor have they been permitted to make good the cumulative losses of the war period, nor has it been possible for them to make the deferred betterments to meet adequately the growing demands of the service.

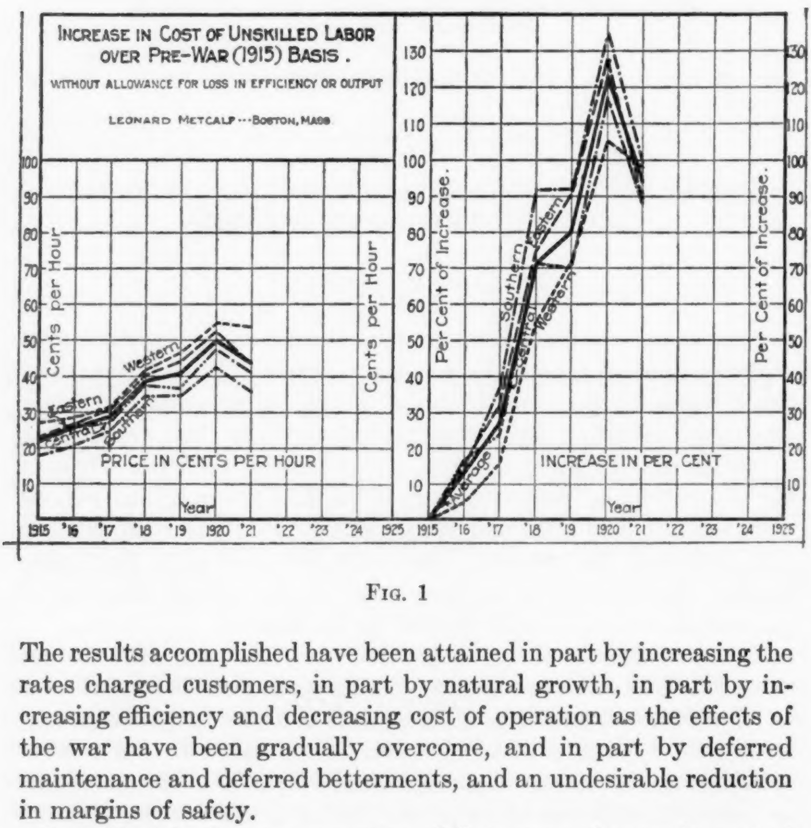

FIG. 1

The results accomplished have been attained in part by increasing the rates charged customers, in part by natural growth, in part by increasing efficiency and decreasing cost of operation as the effects of the war have been gradually overcome, and in part by deferred maintenance and deferred betterments, and an undesirable reduction in margins of safety.

In table 1 is shown a summary of data upon changes in cost of unskilled labor and of materials used in the construction, maintenance and operation of water works from 1915 to 1921. The cost of contract labor, such as ordinarily used in construction, was of course

much higher during the war period than that of the permanently employed labor used in maintenance and operation. It is to be borne in mind, too, that the maximum reduction in efficiency was probably at least 50 per cent at the peak or worst period.

Labor costs. The cost of unskilled labor reached its peak shortly after the presentation of the last report to the 1920 Convention, the average cost for all works reporting, for the year 1920, being 50 cents per hour, while the average cost in 1921 was 43.5 cents per hour, and the present average rate is probably about 40 cents. The average price for 1920 represented an increase of 123 per cent over pre-war (1915) prices; the average for 1921, 94 per cent in excess of the 1915 prices,—both without allowance for decline in efficiency or output.

The data, both as to prices and percentage changes, are shown in diagrammatic form on figure 1. It will be noted that the reduction, both in price and percentage, has been much less marked in the western group than in other sections of the country.

The increase in efficiency of labor has probably been somewhat more pronounced than the reduction in price,—the efficiency or output has returned from 50 per cent below normal, to normal, broadly speaking.

Cast-iron pipe prices. When the last report was made to this Association, two years ago, prices of cast-iron pipe were practically three times normal pre-war prices. In 1920 they rose somewhat further. The average for 1921 was a little more than twice pre-war prices, and at the present time the price is probably a little less than twice that which prevailed before the war. It appears to be abnormally high still and out of line with pig-iron and steel prices and with the price level of other manufactured products as well as of labor, seriously retarding the betterment of water works.

The prices of valves and hydrants, which never reached so high a plane during the war as that of other materials, continued to rise in 1920 and receded in 1921 to a figure somewhat higher than that which prevailed in 1919. The fluctuations were less marked than in the case of cast-iron pipe.

It may be of interest to compare with the percentage increases in cost of unskilled labor and materials to water works, over pre-war basis, shown in table 1, the percentage increases during the period from 1916 to 1921, indicated by the index numbers of various agencies shown below.

TABLE 1

Summary of data upon increase in cost of unskilled labor and materials to water works in the United States, from prewar basis (characterized by 1915 costs) up to 1921

ITEM	NUMBER OF RECORDS ON DIFFERENT YEARS	PRICES PER UNIT							PER CENT INCREASE OVER 1915 (PREWAR BASIS)					
		1915	1916	1917	1918	1919	1920	1921	1916	1917	1918	1919	1920	1921
1. Unskilled labor in cents per hour														
(a) Eastern Group	15–18	23.0¢	26.7¢	30.4¢	40.2¢	43.8¢	52.5¢	43.4¢	16	32	75	91	128	87
(b) Central Group	17–12	21.7¢	25.3¢	26.9¢	37.2¢	36.8¢	47.1¢	40.9¢	17	24	71	70	117	88
(c) Southern Group	6–12	17.9¢	20.6¢	24.5¢	34.3¢	34.4¢	42.1¢	35.7¢	15	37	92	92	135	99
(d) Western Group	7– 8	27.0¢	28.5¢	31.4¢	41.8¢	46.4¢	54.7¢	53.5¢	5	16	55	72	105	98
(e) Average of groups.........		22.4¢	25.3¢	28.3¢	38.4¢	40.4¢	50.0¢	43.5¢	13	27	71	80	123	94
2. Cast iron pipe per 2000 pounds approx.	17–44	$24.23	$30.70	$51.60	$67.74	$69.20	$76.53	$52.30	27	113	179	184	216	116
3. 6 inch valves	11–40	11.18	12.64	19.13	19.13	20.73	24.72	21.93	13	71	71	85	121	96
4. 12 inch valves	3–38	34.78	41.53	65.22	65.02	59.66	68.90	62.13	19	88	87	72	98	79
5. 2-way hydrants	6–38	26.69	32.04	43.13	51.80	47.16	52.30	47.10	20	62	94	77	96	77
6. Coal per 2000 pounds														
(a) Eastern Group	13–15	$2.98	$3.80	$5.96	$6.00	$5.41	$7.34	$5.81	27	100	101	82	146	95
(b) Central Group	8–12	2.41	2.77	3.75	4.53	4.55	5.84	5.69	15	56	88	89	142	136
(c Southern Group	7–12	1.92	2.01	3.03	3.89	3.78	5.35	4.45	5	58	102	97	179	132
(d) Western Group†	5– 4	3.97	4.37	6.31	7.92	4.70	5.60	5.29	10	59	99	18†	41	33
(e) Average of groups.........		$2.82	$3.24	$4.77	$5.57	$4.61	$6.22	$5.43	15	69	97	63	121	92

7. Fuel Oil in cents per														
gallon, South........	1- 3	1.80¢	1.80¢	2.00¢	4.28¢		2.35¢	2.93¢	0	11	138		30	62
West.........	1- 4	1.38¢	1.50¢	2.57¢	4.05¢	4.09¢	4.16¢	4.16¢	9	86	193	197	201	201
8. Alum, per pound														
(a) Eastern Group		1.12¢	1.72¢	1.48¢	1.45¢	1.66¢	1.90¢	1.75¢	54	33	29	48	69	57
(b) Central Group		0.91¢	0.91¢	1.25¢	1.50¢	1.40¢	2.66¢	1.86¢	0	37	65	54	192	104
(c) Southern Group		1.08¢	1.38¢	1.48¢	1.78¢	1.56¢	2.17¢	1.81¢	28	37	65	44	101	67
(d) Western Group		1.14¢	1.21¢	1.51¢	1.53¢	1.79¢	2.04¢	2.23¢	6	32	34	57	79	96
(e) Average of groups.........		1.06¢	1.30¢	1.43¢	1.56¢	1.60¢	2.21¢	1.84¢	22	35	47	51	108	73

* Range $50.60 to $83.50 per ton

† Small number makes record of doubtful value.

In the case of the United States Department of Agriculture figures the pre-war price basis is determined by that for the year 1915; for Dun's and Bradstreet's indices, the average of years 1912–13–14; and for *Engineering News-Record*, 1913.

The fluctuations in gross annual revenue, operating expenses, including taxes, and in net revenues applicable to depreciation, interest, dividends and surplus, expressed in percentage over pre-war conditions, as exemplified by those of the year 1915, are shown in table 2 and figure 2, in average amounts and for geographical groups.

It is to be noted that gross revenue, which lagged behind in normal rate of growth from 1915 to and including the year 1919, has grown more rapidly during the years 1920 and 1921.

TABLE 2

YEAR	U. S. DEPARTMENT AGRICULTURE	DUN'S	BRADSTREET'S	ENGINEERING NEWS-RECORD
	per cent	*per cent*	*per cent*	*per cent*
1916	24	21	30	47
1917	76	67	72	81
1918	96	87	106	89
1919	114	88	105	99
1920	144	102	107	151
1921	55	39	25	102
Average for 6 yrs......	85	67	74	93

Operating expenses, which continued to increase rapidly up to and through 1920, have increased very much less in 1921. Indeed in the case of the Southern Group there has been an actual decrease in the operating expense of 1920 as compared with 1921, and in many works there has been a decrease in per capita cost of operation.

The net revenue increased at a very slow rate to and including the year 1920. It has improved very materially in the year 1921. The average percentage increase for all groups has recovered to a point but little below the line of increase normal *for pre-war conditions* assumed in 1918 and carried forward as a straight line since that time, as shown in figure 2, though it is far below the plane of present price levels.

In the paper presented in 1919, the statement was made that "the net revenue of water works usually increases at the rate of from 4 to 5 per cent compounded annually." The straight line in figure 2,

marked "Normal Increase," corresponds to an increase of 3.9 per cent annually without compounding and is, therefore, somewhat below the position which it would have had if the annual increments

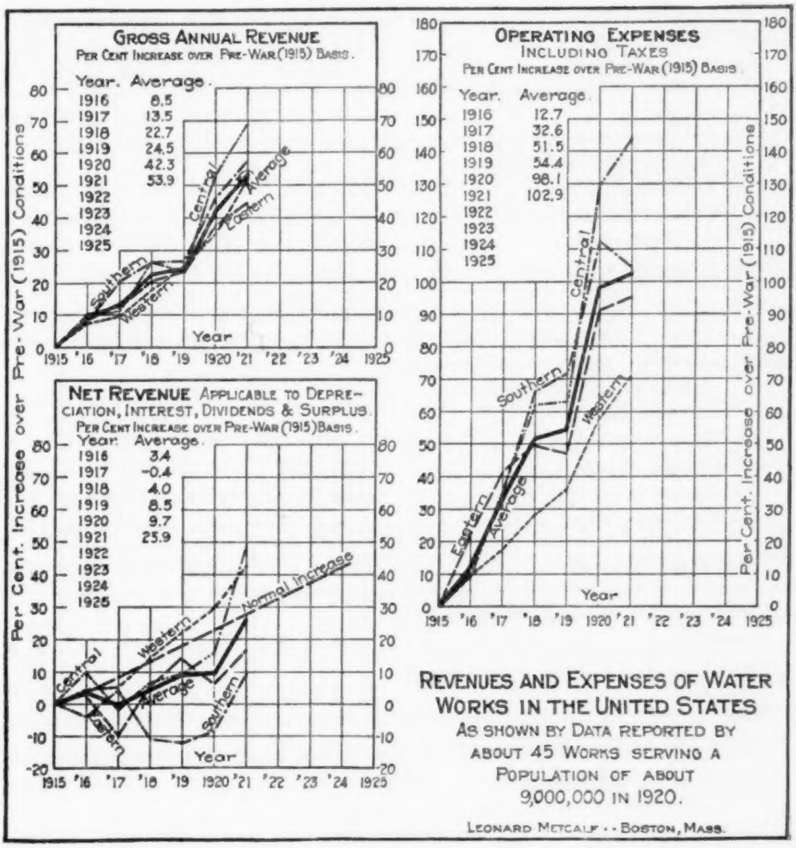

FIG. 2

had been compounded, but the difference is not great and it is interesting to compare the actual conditions developed, with the forecast then made. These differences are shown on the three last lines at the end of table 3.

TABLE 3

Increase in revenues and expenses of water works in the United States over those of 1915, in percentage

	YEAR					
	1916	1917	1918	1919	1920	1921
Gross annual revenue						
(*a*) Eastern group	10.1	12.8	20.6	23.3	37.4	44.6
(*b*) Central group	9.1	11.4	26.4	23.3	53.1	68.9
(*c*) Southern group	7.5	20.3	26.3	26.3	45.9	57.5
(*d*) Western group	7.3	9.5	17.5	25.0	35.6	51.9
Average	8.5	13.5	22.7	24.5	42.3	53.9
Operating expenses and taxes						
(*a*) Eastern group	21.9	41.1	49.7	47.1	91.3	95.3
(*b*) Central group	9.3	37.3	62.3	63.1	129.0	143.9
(*c*) Southern group	9.7	34.6	65.9	71.5	112.6	104.3
(*d*) Western group	9.9	17.4	28.0	36.1	57.7	70.8
Average	12.7	32.6	51.5	54.4	98.1	102.9
Net operating revenues applicable to depreciation, interest, dividends and surplus						
(*a*) Eastern group	3.0	−9.6	5.8	14.5	6.3	16.6
(*b*) Central group	10.0	−1.5	6.5	9.3	16.0	49.3
(*c*) Southern group	−3.7	4.0	−10.9	−12.0	−8.5	9.3
(*d*) Western group	4.3	5.3	14.4	22.1	29.6	42.3
Average (actual)	3.4	−0.4	4.0	8.5	9.7	25.9
Normal if 4 per cent compounded annually	4.0	8.2	12.5	16.9	21.7	26.5
Normal if 5 per cent compounded annually	5.0	10.3	15.8	21.6	27.6	34.0

A study of figure 2 and of the last three lines of table 3, indicate the following comparison:

Percentage increase, over pre-war amount (in 1915) of net operating revenue, applicable to depreciation, interest, dividends and surplus, covering six year period from 1916 to 1921 inclusive

	TOTAL IN 6 YEARS	AVERAGE PER YEAR
	per cent	*per cent*
Actual Normal	51.1	8.5
Normal compounded annually at 4 per cent	89.8	15
Normal compounded annually at 5 per cent	114.3	19

Expressed in words, this indicates that,

First, the *actual growth in net revenue* during the six year period from 1916 to 1921 inclusive, has been about one-half of that normal for the growth in population and service during this period under *pre-war price and fair return conditions*, despite the effect of such increase in rates as was actually granted in many parts;

Second, the present average net return is slightly below normal *pre-war* basis;

Third, the cumulative losses to the water works of this country, both publicly and privately owned, of this six year period (1916–1921), have not been amortized, nor can they be on the present rate basis within a reasonable length of time;

Fourth, while many works have been granted increases in rate which will probably enable them to maintain credit and to make much needed betterments and extensions of plant and service, this is not yet true of the average plants. Many yet remain, therefore, the rates of which will have to be still further increased, if desirable standards of service are to be maintained.

Assuming that the "normal increase" line in the net revenue diagram of figure 2 does represent the increase in net revenue which might normally have been expected under pre-war conditions, (though as has been shown, it is really below a normal rate of increase), it is interesting to estimate approximately the extent to which the water works of the country have suffered from the failure to earn the revenue which should normally have accrued to them *under pre-war conditions*. Applying the differences between the assumed normal increase and the actual gain in net revenues for the various districts into which the country has been divided, and making approximate computations, it appears that the works represented by these reports have suffered a loss of upwards of $6,000,000 by the failure to earn the net revenues which might normally have been expected, during the years 1917 to 1921 inclusive. If the same ratio were assumed to hold for the entire country, with some allowance for the small proportion of the population not served by water works, it seems probable that the total loss to the water works of the country has approximated $50,000,000 on *pre-war normal basis*. If proper recognition be given to the higher plane of war and post-war conditions, the amount below a fair return would probably be from four to six times as great, or say roughly, $250,000,000. Or to express the matter in a different way, the water works of this country

are on the average back again on the deflated pre-war income basis, though they are still carrying the losses accumulated during the war, whereas the general loss in purchasing power of money or increase in costs would probably justify an average increase in net revenue over pre-war basis of at least 30 per cent, and probably as great as 40 per cent or even more in some cases.

These later studies indicate the soundness of the earlier conclusion that the regulatory authorities have found it impossible, under war conditions, at least, to remove the hazard of investment and burden of loss in such enterprises, and that the rate increases granted were not only inadequate but lagged behind the adverse conditions by at least eighteen months.

The financial problem involved is not yet solved. It is a difficult thing, practically, to increase rates now, where an inadequate increase was granted during the war period,—in the face of lower and yet declining prices. But such increase is essential in many, if not most cases, if desirable standards of service are to be maintained. The public wants, is entitled to have, and is ready to pay for a really high standard of service. The difference in cost to the family, between the good and the mediocre or inadequate service, is probably considerably less than is spent by many a family in chewing gum. Water service is by far the cheapest of all public services and easily within the resources of the public.

The public and the individual have a right to demand that the water service shall be good in every respect and that fair margins of safety shall be maintained.

The administrators and regulators of water works have no right to carry the hazards and to take the chances incident to a water supply which is inadequate, either in quality, quantity, or pressure.

The war is past and sound economic doctrine demands that the water works should be re-habilitated first of all, as they are the utilities most important to the public health and they involve the least cost to the public.

It is encouraging to note that, despite the difficulties involved, some of the Utilities Commissions are coming to sense the inherent dangers of the situation and the desirability of somewhat more liberal standards than those of the past. Already several have considered means of amortizing losses of the war period, recognizing that failure to do so must have the inevitable effect of retarding recovery.

It is with the water works as with the individual. To deny good food and living conditions and normal hope of recovery to the patient recuperating from a long and serious illness is but to court death or further continued burden of expense: whereas a friendly attitude and atmosphere of encouragement, with occasional assistance from a competent doctor, on the other hand, hasten recovery and lighten the burden of all.

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REPORT OF AN INVESTIGATION OF CONDENSER PERFORMANCE IN THE ST. LOUIS WATER DEPARTMENT[1]

By L. A. Day[2]

About a year ago it was realized that the vacuums of our triple expansion pumping engines were not all that might be desired. We decided, therefore, to make a thorough study of our condensing apparatus, with a view of increasing the vacuum on all of our pumps. Our investigations were made on an engine at the Bissell's Point station. One was selected whose vacuum was particularly poor. The condenser on this engine is of the surface type with a two pass water travel through the tubes. The condenser is installed away from the main suction pipe but it is piped to the same. Water is shunted by means of a damper in the suction pipe of the pump to the condenser and discharged, after passing through the condenser, back into the suction pipe. This arrangement lends itself well to the purpose of varying the quantity of cooling water through the condenser.

The first possible fault to be investigated was the steam distribution throughout the length of the condenser. This was done because the engineer in charge of the plant felt sure that the condensor was clean. Temperature measurements along the shell did disclose hotter and colder parts of the condenser, indicating an uneven distribution of the steam through the condenser, but an attempt to correct this situation by rearranging the baffling made no appreciable change. Since we assumed the condenser was clean, the presence of air in the condenser was next investigated, proceeding as follows:

The necessary apparatus consists of a glass U-tube, half filled with mercury, at least 32 or more inches long, two low-reading thermometers, (reading up to 200°F. being ample) and a barometer.

[1] The first of a series of papers being prepared under the auspices of Committee No. 7, on Pumping Station Betterments.

[2] Chairman of Committee on Pumping Station Betterments; Mechanical Engineer, St. Louis, Mo.

The U-tube is connected into the condenser near the air pump suction. One thermometer, inserted into a thermometer well at the steam entrance to the condenser, records the vacuum temperature. The other thermometer is inserted into a thermometer well at the bottom of the condenser near the air pump suction. The latter records the vapor temperature at this point, from which the vapor pressure may be obtained by reference to the steam tables. The barometer is hung preferably near the U-tube so that the temperature of the mercury in both the barometer and U-tube are the same, which will avoid the necessity of correcting the lengths of the mercury columns to the same temperature. The U-tube has the pressure of the atmosphere on one leg and the pressure in the condenser on the other leg, the difference in the height of the legs, therefore, being a measure of the difference between the atmospheric pressure and that in the condenser. The barometer has the pressure of the atmosphere on one side and a practically perfect vacuum on the other side of the mercury column, hence it measures the difference between the atmospheric pressure and that of a perfect vacuum. The difference between the barometer reading and that of the U-tube is then a measure of the pressure in the condenser above the perfect vacuum and is known as the absolute pressure.

It is usual to express the absolute pressure in the condenser in terms of a vacuum in inches of mercury below the atmospheric pressure, when the barometer is at 30 inches. The mean atmospheric pressure at sea level is 14.7 pounds per square inch, which corresponds to a height of 30 inches of mercury at 58.4°F. If the barometer and vacuum column are corrected to a temperature of 58.4°F., then the difference between the two will give the absolute pressure within the condenser in inches of mercury at 58.4°F. If this difference is subtracted from 30 inches, we have the number of inches of vacuum referred to 30 inches barometer. There are tables and charts available for making these corrections published by the leading condenser manufacturers.

The absolute pressure is thus obtained corrected to a 30-inch barometer. If no air were present in the condenser but only water vapor, this pressure would be equal to the vapor pressure in the condenser, corresponding to the temperature of the vapor, which is measured by the thermometer near the wet vacuum pump suction. If we look up the vapor pressure (in the steam tables for condenser work expressed in inches of mercury referred to a 30-inch barom-

eter), and find it to be lower than the absolute pressure, then the difference between the two is attributed to air and is, by Dalton's laws, a measure of the air pressure in the condenser in inches of mercury.

As stated before, the reading of the thermometer at the wet vacuum pump suction was taken to determine the vapor pressure, rather than the one in the steam entrance to the condenser, the former being at the bottom of the condenser where the air is present in greatest amounts, as will be shown later.

Having applied these principles to the condenser of the pump in question it was found that the air pressure was excessive. Good practice does not permit more than ½ inch of mercury. The air pump, which is of the type that handles both the air and water, as is common on large pumping engines, has a piston ring of 3-inch depth, made in two halves and is held out against the cylinder walls with flat springs. The cylinder was found to be sufficiently true to bore so that by setting out the ring the piston became practically water tight. When this was done the vacuum rose from 28 to 28½ inches. This happened in mid-winter when the circulating water in the condenser was coldest for the year. As the spring season progressed and the circulating water became warmer, the vacuum again dropped off, until at the end of May it was down to 26 inches with an air pressure of less than ½ inch. It was now decided, despite the information that the condenser was clean, that it must be dirty, for the temperature difference between the steam end thermometer or the vacuum temperature, and that of the out going circulating water was 42.9°F. The heat transfer was only 87 B. t.u. per square foot of condenser surface per hour, a very low figure. It was decided, therefore, to clean the condenser and, as anticipated, the condenser tubes were coated with a very heavy scale. After cleaning it the vacuum rose to 27.9 inches, with 0.45 inches of air and a heat transfer of 237 B.t.u. Later, in winter, when the circulating water was again cold, the vacuum rose to 29 inches.

Tabulating these values we have (see table 1).

Item 5 equals items 3–4. Item 6 equals 30 inches—item 5. Item 8 is taken from steam tables (referred to a 30-inch barometer) for pressure corresponding to item 7. Item 9 equals items 5–8. Item 11 is taken from steam tables (referred to a 30-inch barometer) for vacuum corresponding to item 10. For practical purposes, item 16 may be found by measurement of the quantity of circulating

water per hour, W pounds, noting its temperature rise and proceeding as follows: W $\times$ (Items 14–13) $\div$ (square feet of heating surface $\times$ items $10 - \frac{13 + 14}{2}$), or if the steam consumption per hour, S lbs., is known, item 16 may be found as follows: S $\times$ latent heat at temperature of item 10 $\div$ (square feet of heating surface $\times$ items $10 - \frac{13 + 14}{2}$).

Summarizing the results, when air is present much in excess of ½-inch of mercury pressure there is either a major leak in the packing of the valve or piston rods, or the air pump leaks badly in its valves or around its piston. When the air pressure is satisfactory and the vacuum is still low, a dirty condenser will be indicated by a low heat transfer, which may be recognized from item 15, which is the temperature difference between the vacuum and outgoing circulating water. This (item 15) should not be over 15° in good practice; note that in the table, before cleaning the condenser, this difference was 42.9°F., and after cleaning 12.2°F. The last difference of 24°F. and 29 inches vacuum indicates that too much circulating water was going through the condenser, because, although a high vacuum was obtained, the condensate was cooled too much, incurring a waste of heat (Compare items 12).

TABLE 1

1. Date	May 24	June 17	Winter
2.	Before cleaning	After cleaning	After cleaning
3. Barometer, corrected	29.65″	29.68″	29.32″
4. Vacum by column, corrected	25.67″	27.59″	28.42″
5. Absolute pressure	3.98″	2.09″	0.90″
6. Vacuum (30″ Barometer)	26.02″	27.91″	29.09″
7. Vapor or condensate temperature	120.5°	94.7°	58.0°
8. Vapor pressure (30″ Barometer)	3.50″	1.64″	0.48″
9. Air pressure	0.48″	0.45″	0.42″
10. Exhaust steam temperature	125.0°F.	103.2°	76.5°
11. Corresponding vacuum	26.04	27.88	29.08
12. Items 10–7, circulating water	4.5°F.	8.5°	18.5°
13. In, temperature	73.2°F.	81.5°	43.0°
14. Out, temperature	82.1°F.	91.0°	52.5°
15. Items 10–14	42.9°F.	12.2°	24.0°
16. Heat transfer	87 B.t.u.	237 B.t.u.	145 B.t.u.

And now we come to the question of what is a proper vacuum for a triple expansion crank and fly-wheel type of pumping engine.

Figure 1 shows the results of duty tests made on the same pump, keeping all conditions but the vacuum constant. Note that there

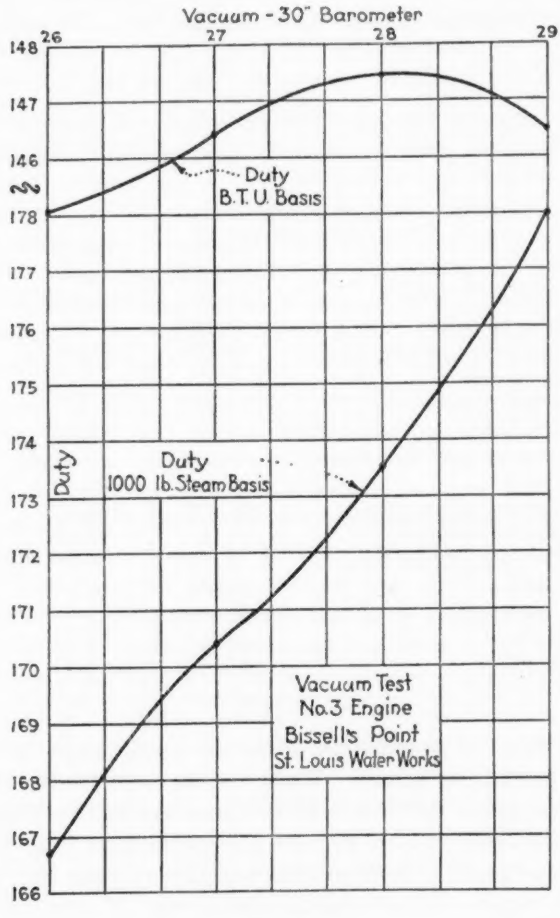


FIG. 1

is but little variation in the duty (B.t.u.) between a 27-inch and a 29-inch vacuum. The duty on the B.t.u. basis is a true measure of the heat input into an engine for a certain output, i.e. the heat input which has to be supplied by the boilers, which is the difference

in heat content between the steam and the condensate or feed water. On the same chart is also plotted the variation of duty on the 1000 pounds of steam basis with vacuum, which shows a rapid increase up to 29-inch vacuum. It shows this increase because it does not take into consideration the heat rejected in the condensate (compare items 6, 7, 12 and 15) and is therefore a misleading index of how economically the pumping engine is operating. From figure 1, it is seen that a 28-inch vacuum is better for operating economically than a 29-inch vacuum, provided an increase in the temperature of the air pump discharge water can be utilized to advantage, and that in the winter months, although it were possible to obtain a higher vacuum due to the cold circulating water, it will be well to throttle the circulating water to the condenser, not cool the condensate

TABLE 2

PRESSURE DUE TO AIR, INCHES OF MERCURY	B. T. U. EXTRACTION	
	Upper half	Lower half
	per cent	*per cent*
2.9	81	19
2.76	72	28
2.07	75	25
1.9	70	30
1.42	70	30
0.48	45	55

excessively, and maintain a lower vacuum, or install a feed water heater in the exhaust pipe, if the circulating water in the condenser can not be controlled.

It was previously mentioned that air was mostly present at the bottom of the condenser. The following table shows the distribution of work between the upper and lower halves of condensers for different quantities of air present.

Consequently when air is removed from a condenser the entire surface of the tubes becomes effective. To show further the presence of air in the bottom, readings taken on the same condenser gave an air pressure at the steam inlet of 0.017 inch and at the vacuum pump suction of 0.64 with an absolute pressure of 1.58 inches. Excess air was then admitted to the condenser so that the absolute pressure increased to 2.2 inches, when the air pressure at

the steam inlet measured 0.008 inch and at the vacuum pump suction 1.265 inches. These values show the effect of air presence to be negligible at the steam inlet of the condenser. As a consequence the temperature of the vacuum taken there is practically a true measure of the vacuum. Referring to table No. 1, note the agreement between items 6 and 11, the latter having been determined from the steam temperatures, item No. 10.

A DEPARTURE IN PIPE FOUNDRY PRACTICE[1]

By Peter Gillespie[2]

That fewer examples of the craftsmanship of the ancients exist in iron than in either brass or copper is probably due less to the sequence of their discovery, than to the fact that the former metal is susceptible to corrosion while the others survive the centuries and defy decay almost indefinitely.

It is one of the most natural of conjectures that the discovery of the usefulness of iron was made by some prehistoric savage who, having built his fire on or near a mass of iron stone, afterwards observed the metallic beads produced through the deoxidizing of the ore by his fire. These beads had the constitution of wrought iron or steel or cast iron of the present day, depending on the degree to which the combination of the metal with the carbon of the fuel had taken place. Malleability, hardness and brittleness were doubtless discovered by him or his fellows and the effect of quenching the material while hot in certain cases also was probably known. In Homer's Odyssey, I–IX, the hissing of the olive-pointed stake driven by the hero Ulysses into the eye of Polyphemus is likened to the hissing of steel quenched by the smith in water for purposes of hardening:

"And as when a smith dips a great axe or adze in cold water amid loud hissing to temper it—for therefrom comes the strength of the iron—even so did his eye hiss round the stake of olive wood."

As Homer flourished nearly 1000 years before Christ, and as this art was apparently a common one in Homeric times, some idea of its antiquity may be obtained from the reference.

Cast iron was made in Sussex, England, in the fourteenth century, and in the sixteenth cannons weighing three tons were cast from it. The fuel used until that time was charcoal made from forest timber, the favored method of creating an artificial draft being by water power. Early in the seventeenth century, Dud

[1] Presented before the Philadelphia Convention, May 17, 1922.

[2] Professor of Civil Engineering, University of Toronto, Toronto, Canada.

Dudley in England produced cast iron successfully, using coke as fuel. This advancement in the art is usually attributed to the legislation of the Elizabethan period, forbidding the cutting of timber for iron making and preventing the erection of iron foundries in certain sections of that country.

While the intervening centuries have witnessed the introduction of the modern blast furnace and cupola, the use of flux, the preheating of the blast and the application of the sciences of metallurgy and chemistry generally to the production of iron and its alloys, it is also true that there has been less development in the art of producing iron castings than in that of most other engineering commodities and this notwithstanding the fact, that they enter so very largely into structures and machines of almost every kind. It is proposed here to describe briefly a comparatively recent but distinct advance in the founder's art, the making of iron pipe by the de Lavaud centrifugal process.

The problem of employing a revolving mould in the process of casting is one that for generations has appealed to the inventor, and it is indeed astonishing that developments along this line have been so long delayed. The history of early attempts to solve it is one marked mostly by failure in which the names of Eckhardt, Taylor and Wailes, Huth and others appear. No significant progress in the application of the method to commercial production in the metal industry seems to have been made until quite recently. Although it is now employed in the production of articles of non-metallic and non-ferrous composition, it is with the manufacture of cast iron bell and spigot pipe with which this article is primarily concerned.

For the manufacture of cast iron by the de Lavaud process, a plant consisting of a cupola, a revolving water-cooled moulding machine, an annealing furnace and a dipping vat is required. The molten metal is first transferred from the cupola to a tilting ladle at one end of the machine. This ladle holds slightly more iron than is required for a single pipe of the size to be cast. By an ingenious and perfectly controlled hydraulic device, this ladle can be made to discharge its contents into a cantilevered water-cooled trough which projects into the interior of the revolving mould and from the forward end of which iron is permitted to discharge in a stream lying nearly in the plane of revolution.

The machine includes an accurately made hollow cylindrical mould whose inner dimensions are identical with the outer dimensions of

the finished pipe, including the enlarged bell end. This mould is revolved on its axis by an impulse water wheel integral with it, inside a cylindrical stationary casing, the annular space between the two cylinders being filled with cooling water which is continually changing under a moderate pressure maintained at the inlet end. Escape of this water at the ends of the machine between the moving mould and the stationary casing is prevented by the use of gland-like rings somewhat similar to collar thrust bearings employed in marine work. The revolving mould is supported at two points in its length by two sets of friction rollers which have bearings on the inside of the casing and are lubricated by grease cups accessible from the outside. To shape the inside of the bell a single small core is used—the only one employed. This provides an annular shelf for the centering of the spigot and the undercut chase in the bell for the reception of caulking lead when the pipes are jointed in service. No bead is provided at the spigot end, this feature being omitted in order that the pipe may be drawn from the mould after solidification of the iron has taken place. The casing and its contained mould are made to travel back and forth on horizontal ways by means of a hydraulic cylinder installed beneath the casing.

Assume the tilting ladle filled with the necessary quantity of molten iron and the movable casing run forward so that the extremity of the cantilevered trough registers even with the remote end of the mould which is always the bell end. The turbine is started and when the mould has acquired its proper speed, the tilting ladle is tipped forward discharging its contents into the cantilevered trough. The observer at the bell end signals the first appearance of the molten metal at his end of the pipe whereupon the operator in charge of the hydraulic cylinder immediately starts the backward movement of the casing on its ways. The fluid iron is thus supplied to the mould continuously right out to the spigot end. In contact with the cool revolving mould it solidifies in a few seconds and shrinks from the mould slightly but sufficiently to be withdrawn therefrom by a special hook that engages the spigot end when the casing is again moved on its ways in the forward direction. The pipe is then passed directly to the annealing furnace in which case its residual heat is conserved or is allowed to cool in air. The normal output from a machine is fourteen 6-inch pipes per hour, the operating gang numbering seven men.

The process of annealing comes next. The furnace is oil-fired. In it, the equivalent of five 6-inch pipes may be treated simultaneously. By a mechanism, these pipes are slowly revolved as the blast plays on them so that all portions are equally heated. This prevents warping and secures uniformity in quality in all parts of the pipe. The temperature is controlled by optical pyrometers.

Class "C" pipes manufactured for waterworks service in accordance with the specifications of this Association have for 4-inch, 6-inch, and 14-inch sizes, weights of 23.3, 35.5 and 116.7 pounds per lineal foot respectively. De Lavaud pipes of the same nominal sizes have weights of 15, 24 and 62.5 pounds per lineal foot respectively.

Tests of pipe material

The metal in de Lavaud pipes is a fine grained gray iron, uniform in appearance and texture, remarkably free from blow holes and slag pockets and having a wall of thickness surprisingly uniform. From time to time the writer has conducted tests on these pipes and on samples of metal cut therefrom for the purpose of comparison with materials cut from sand mould pipes poured from the same heat. In one instance, the two materials when analyzed gave the following results:

CONSTITUENT	MACHINE MADE PIPE	SAND CAST PIPE
	per cent	*per cent*
C.	3.45	3.67
Mn.	0.49	0.61
S.	0.053	0.044
P.	0.563	0.654
Si.	2.48	2.00

The tensile strength of the machine made cast iron was 37,000 pounds per square inch; that of the sand mould iron was 16,000 pounds per square inch.

The modulus of rupture in cross-bending for the former material was 64,000 pounds per square inch; for the latter 34,000 pounds per square inch.

The resilience in inch pounds per cubic inch determined from cross-bending was 20 for the former and 10 for the latter. The modulus of elasticity determined also from cross-bending, was 15,400,000

pounds per square inch for the former and 8,600,000 pounds per square inch for the latter. Roughly, therefore, *the strength both in tension and cross-bending, the resistance to shock and the stiffness are about twice as great for machine made iron as for the sand cast product.*

In another and more recent series, the tensile strength of the machine made product averaged 40,000 pounds per square inch; that of sand cast iron, 18,000 pound per square inch. The modulus of rupture averaged 59,000 pounds per square inch for the former and 37,000 pounds per square inch for the latter, each item being the

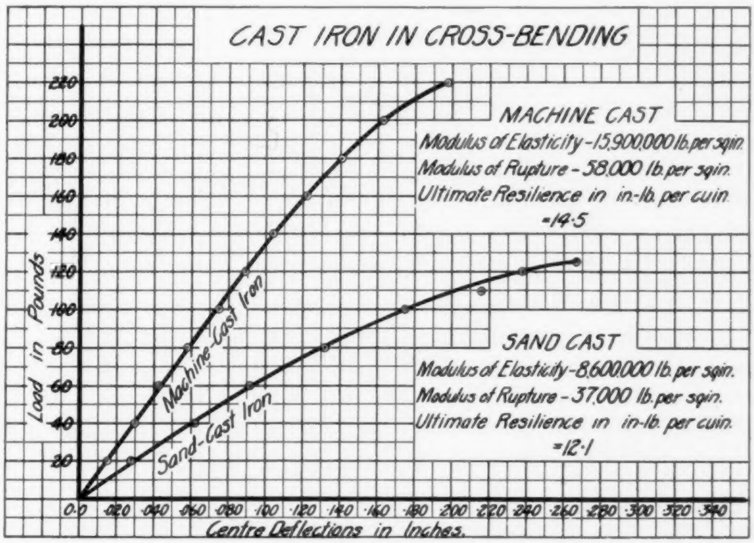


FIG. 1

average of four determinations. Two typical deflection curves, plotted from cross-bending tests, made on specimens approximately half by quarter inch cross-section and of span $11\frac{1}{2}$ inches are shown on figure 1. The disparity in the resilience factors is much less than that quoted above but there is notwithstanding substantial agreement otherwise. In interpretation of the modulus of elasticity as evaluated above, it may be said that were there two pieces of cast iron, one of each class, each 100 feet long and each subjected to a tensile stress of 10,000 pounds per square inch the stretch in the machine made pipe would be 0.75 inch while that in the sand cast

pipe would be 1.4 inches. Other things being equal, the stretch is less for the more rigid material. A 6-inch pipe tested by the writer recently sustained an internal hydrostatic pressure of 2100 pounds per square inch without failure. As the walls were 0.32 inch thick and the internal diameter was 6.25 inches, the circumferential tensile stress in the metal shell was practically 20,000 pounds per square inch. It was the intention to test this pipe to destruction, but the end gaskets gave out at the pressure indicated and the idea of testing to failure had to be abandoned.

Accurate determinations of the weight per cubic foot showed that the two materials differed but little in this respect. This weight was 433 pounds per cubic foot for each class.

CONSTITUTION OF CAST IRON

Cast iron in the molten state is a solution of carbon in iron. When cooled the carbon may be present (*a*) as precipitated graphite, in which case the iron is "gray," or (*b*) in the form of a compound of carbon and iron called cementite (Fe_3C), in which case "white" iron exists, or (*c*) and, perhaps more frequently, partly as graphite and partly as cementite. "Ferrite" is the name applied to pure iron and "pearlite" to a combination of ferrite and cementite in alternate laminae. Slow cooling tends to the production of graphitic carbon, while "chilling" produces the hard cementite characteristic of white irons. Now if chilled irons be exposed to a temperature sufficiently high and of sufficiently long duration, the carbon tends to graphitize, that is the iron tends to change from white to gray. The temperature necessary to accomplish this depends upon the composition of the iron, but must exceed 730°C. It will be obvious, then, that the constitution and properties of an iron containing, say, 3 per cent of carbon, may be quite uncertain depending upon the manner in which the carbon exists therein. It may consist of: graphite 3 per cent, and ferrite 97 per cent, in which case the iron will be gray and soft. Remembering further that iron combines with carbon to form cementite in the ratio of 14 to 1, there may also result a product of the composition, cemetite 45 per cent and ferrite 55 per cent, in which case the iron is white, hard and brittle. A portion of these two constituents would of course go to form pearlite. Again, supposing that one-third of the carbon exists in the form of cementite, there would result cementite 15 per cent, ferrite 83 per cent, and graphite 2 per cent. The first two ingredients totalling 98 per cent of the

whole, constitute a matrix of pearlite in which the flakes of graphite are interspersed and which in consequence is weakened thereby. It should be remembered that graphitic carbon, if present in large flakes, is a cause of lowered strength.

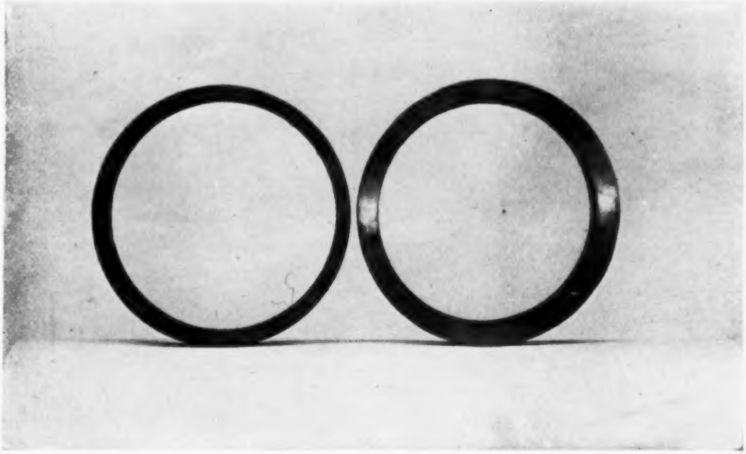


FIG. 2. WALL THICKNESSES OF MACHINE-MADE PIPE (LEFT) AND SAND MOULD PIPE (RIGHT)

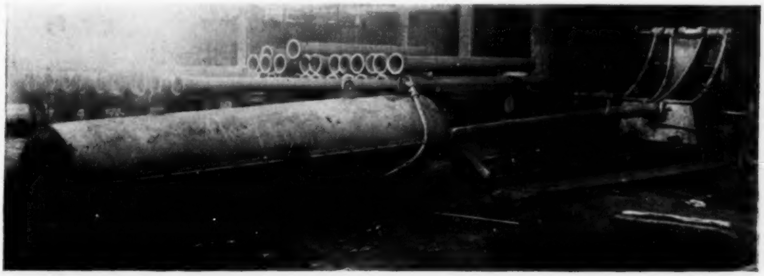


FIG. 3. MACHINE FOR MAKING PIPE

The chilling of the outer layer of metal in pipes made by the de Lavaud process results in the formation there of a thin annulus of white iron. To convert this to a gray iron, the pipes are annealed as stated above. The molecular structure after annealing is different, however, from that of sand cast iron as the accompanying photographs show. The graphite is more finely divided than in the

latter where large flakes of that material are in evidence. The explanation of the greater strength of the machine-made material probably lies in this fact.

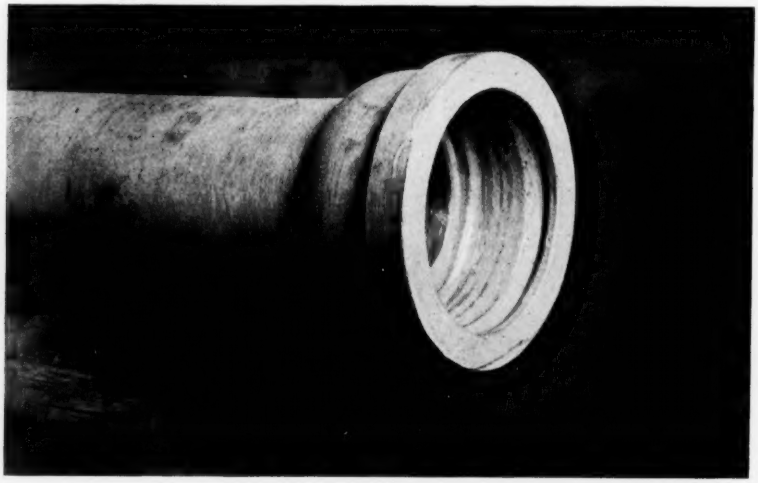


FIG. 4. BELL END OF MACHINE MADE PIPE, SHOWING SHELF FOR CENTERING SPIGOT

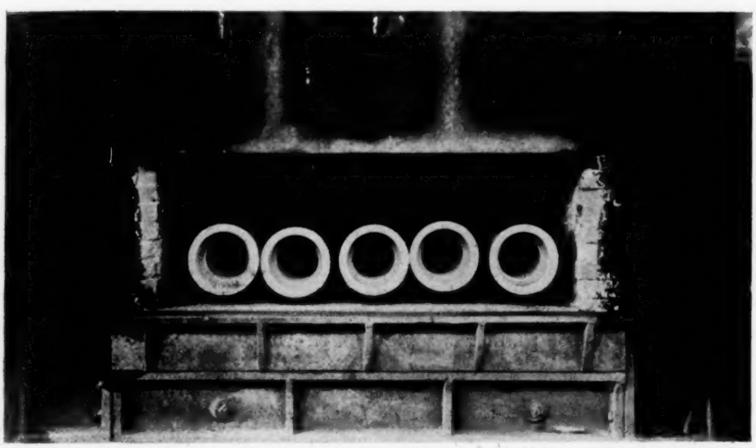


FIG. 5. MACHINE-MADE PIPE IN ANNEALING FURNACE

Further, in the fact that smooth metal rusts more slowly than rough (machine moulded pipe is unusually smooth, especially on its

outer surface), an indication as to long life may be found. Recent researches in the field of electro-chemistry have established fairly well the principle that a metal which is homogeneous in its structure and properties is not likely to develop those differences of electric potential that make for corrosion in service. May not, therefore, the homogeneous structure characteristic of de Lavaud metal be an indication also of its capacity to resist common influences tending toward corrosion?

The de Lavaud process is one that has great possibilities for usefulness and economy. To the manufacturer it means less metal, less

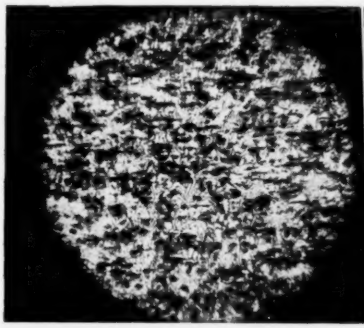


Fig. 6

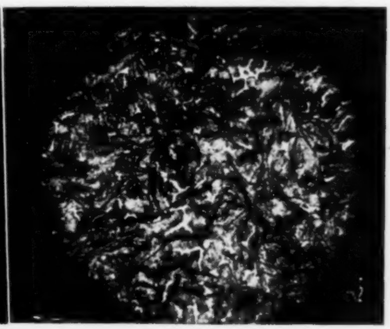


Fig. 7

Fig. 6. Distribution of Graphite in Machine-Made Pipe
Fig. 7. Graphitic Flakes in Sand Mould Pipe

labor, and less foundry space, since areas for storage and mixing of sand and for flasks are not required. Moreover the number of rejections at the point of inspection is remarkably low. These circumstances favor an increased output. To the shipper and the customer, the lessened weight is an important consideration. The user finds the absence of imbedded sand grains a matter of much importance when he comes to machine the metal which he finds of uniform texture, free from blow-holes, easily worked, and capable of taking a clean steel-like thread when tapped for house connections. To him also the smooth interior and greater cross-section of bore for a given outside diameter are circumstances of some account, favoring, as they do, increased carrying capacity. All in all, the development marks a significant advance in the replacement of manual labor by the machine so characteristic of the industrial achievements of the present century.

MICROÖRGANISMS IN THE BALTIMORE WATER SUPPLY

By John R. Baylis[1]

The water supply of Baltimore City is obtained from the Gunpowder River, and has a storage of from a few days to about two weeks in the Loch Raven Reservoir. Most of the time the water overflows the dam, but, in times of low flow, all of it may be diverted to the city. The reservoir is long and narrow, with most of the side slopes for the lower half very steep. Near the upper end and at a few other places, mostly in coves, the water extends over shallow areas which are out of the main flow of the stream. Some of these places offer ideal conditions for the growth of microörganisms other than bacteria.

Growths occur in reservoir. Water entering the reservoir does not contain a great abundance of microörganisms, and those present are mostly diatoms and a few protozoa. On leaving, it frequently has a great variety of various vegetable and animal organisms, some species of which are found in large numbers. In the upper part, in the coves, and along the banks are frequently found growths of algae, forming a film that covers the entire ground surface, from the water's edge to where the depth is too great for their growth. In such places are usually found large numbers of protozoa, rotifera, crustacea, and other animal organisms feeding on the algae. Sometimes, large amounts of this filmy growth break loose, rise to the surface, and gradually float into the main current, where they are carried towards the dam and tunnel inlet. Little of it reaches this point, as most of it is broken up by the small waves and the entrapped gases, causing it to float, liberated. Few of the live algae, except diatoms, reach the Montebello Filters, as they are consumed by the animal organisms, or settle to the bottom.

Conditions of existence. Animal organisms cannot organize food from inorganic substances, and are consequently dependent on vegetable life. Water must have the necessary mineral matter and

[1] Principal Sanitary Chemist, Filtration Plant, Baltimore, Md.

carbon dioxide to support vegetable growth. This is evident by examining the effluent from various springs, some of which will have abundant algae growths, while others will have practically none. It has been suggested that the hydrogen-ion concentration of the water, is one of the main factors affecting the growth of microorganisms. The writer can only partly verify this, for certain forms of algae grow readily in all concentrations from pH of 6.0 to 8.5. The organisms sometimes change the hydrogen-ion concentration considerably, vegetable growths decreasing it when alive, and animal growths and decaying vegetable matter increasing it. Consequently, in reservoirs having both animal and vegetable growths, there is a tendency toward a more or less constant pH value.

The results of a few examinations of springs and small streams fed entirely by springs show microörganisms growing abundantly in a fairly wide range of pH. In collecting the samples from springs and streams, the algae growths were broken loose and mixed with the water, sluggish places being selected.

SAMPLE NUMBER	pH	MICROÖRGANISMS PER CC.			
		Green algae	Diatoms	Protozoa	Miscellaneous and unclassified
1	6.3	39000	6000	Few	300
2	8.5	15450	1200	56	0
3	8.0	550	450	5700	50
4	7.1	50	6500	Few	Few
5	7.6	0	250	0	28

The growth of crenothrix is supposed to be favored by low dissolved oxygen contents, but the tunnel leading from the Loch Raven Reservoir to Montebello Filters, 12 feet in diameter and about 7 miles long, has enormous growths of this organism, with the dissolved oxygen content averaging about 75 per cent saturation. Algae growths live indefinitely in glass stoppered bottles when kept in a warm place and exposed to the sunlight, growths having been kept in the laboratory for over two years with no decrease in number. In fact, the number greatly increased the first year and since then there has been no decrease. Animal organisms and bacteria will not live long under favorable temperature and light conditions, unless more food is occasionally added, or vegetable growths are present. Bacteria will increase rapidly to large numbers in water when stored

under favorable conditions. They will decrease then to a very small number, all dying in one or two years time. Most protozoa are somewhat like bacteria. They will frequently increase, then decrease, and will not increase again unless there is a change of conditions.

A 200 cc. sample of water stored in the laboratory in a glass stoppered bottle shows interesting changes. Nearly three years ago, a small piece of gelatinous growth of bryozoa was placed in a bottle and filled with water from Loch Raven Reservoir. The water at this time did not contain over 500 microörganisms per cc. There were a few of the statoblast of bryozoa present and they have remained unchanged. Shortly thereafter growths of algae were noticed, botryococcus being present in the greatest number and also in standard units, though there were large numbers of scenedesmus, and two or three other forms of algae. A few protozoa, mostly amoeba, and a few free living nematodes were also found.

An estimate in December, 1921, and one in April, 1922, showed over 100,000 organisms per cc. making about 10,000 standards units. The organisms seem to be holding their numbers in approximately the same ratio. On account of the small size of sample, very few pH tests have been made. The water added had a pH value of about 7.0. It was 8.4 in December, 1921, and less than 5.0 in April, 1922. With this wide change in pH, there is no appreciable change in microörganisms. Another sample with a pH of about 7.0, containing only algae, changed to 8.6 in about $1\frac{1}{2}$ years, and is now 8.3. The total number of algae present in this sample are about 125,000 per cc. giving about 10,000 standard units. These samples and the wide variations in pH in some of the springs, indicate that many of the algae are not as greatly affected by pH changes as are bacteria.

Methods of testing. One of the great difficulties in making microscopical examinations is to find a method that will give fairly accurate counts. The writer's experience with the Sedgwick-Rafter method of concentrating the organisms has not been satisfactory, except for non-motile ones. Any attempt to enumerate and classify microörganisms in water containing a large number of motile protozoa, and zoospores and isogametes of some of the common algae, is difficult. Some of the forms are nearly transparent, are so irregular in shape, and resemble so much other matter in suspension, that unless they are motile it is impossible to recognize them as organisms. If they are killed or stunned by a chemical reagent,

many will escape detection, and, if not, the light will attract many of the motile ones to the field of the microscope, resulting in too high counts.

Tests are made twice a week on raw water coming from the Loch Raven reservoir. A 1 cc. Rafter's counting cell and a 10 cc. cell, somewhat similar, are used for counting. A B. & L. 7.5 X micrometer eyepiece with a 5 mm. scale divided in 0.1 and a 16 mm. objective, to give a magnification of 72 diameters, are used for counting the 1 cc. portions in the small cell, and a 48 mm. objective, giving a magnification of 15 diameters, is used for the large cell. A 100-watt gauge micro lamp with daylite glass is used in order to have uniform light conditions. Cover glasses for the counting cells are usually omitted, so as to permit examination of the organisms with considerably greater magnifying objectives, which is frequently desirable in classification and it permits also the organism to be moved or turned over by a sudden movement of slight tilting of the stage of the microscope. Three objectives are used for most work, the two mentioned and a 4.0 mm., giving a magnification of 280 diameters.

There is practically no danger of injury to the objectives by immersing in water, which is necessary when the 4.0 mm. one is used. For greater magnification the 1.9 mm. oil immersion objective is used, and is immersed in the water instead of oil. Several years of such use has resulted in no injury to the objectives. It is difficult to transfer an organism from the counting cell to a slide. It requires considerable time and is unnecessary, unless it is desirable to hold the organism for some length of time. It is better to make the identification at time of counting.

Samples to be tested are allowed to stand several minutes in the counting cell on the stage of the microscope before counting. Most of the organisms settle to the bottom, and fairly accurate results may be obtained by focussing on the bottom part of the water in the cell, unless there are some that will float, such as anabaena. The large cell is used for such organisms as can be readily seen with the 48 mm. objective, which will include the crustacea, rotifera, bryozoa, hydra, coretha larva, and the large protozoa such as difflugia, uroglena and dendrosomá. Most of the large organisms are actively motile and have to be killed by the use of a drop of iodine or formalin, or stunned by a little alcohol. Frequently to determine the species the objective is shifted to a greater magnification, the 16 mm.

usually being sufficient to classify the larger organisms. The entire 10 cc. portions are examined, requiring about 15 minutes unless there are a large number present.

If there are few of the smaller organisms in the water, 500 cc. are filtered to 5 cc. and 1 cc. is placed in the counting cell. Such portion of this 1 cc. is examined as will give a fair estimate of the total number in the concentrated portion. This method has been found to give results varying considerably from the number found when examined without concentration, though the kind of organisms have considerable effect on the number passing the filter. When some forms are prevalent such as the smaller and actively motile protozoa and some of the zoospores of algae, this method of concentrating will give only a small percentage of the number actually present, and sometimes only about 10 per cent. Examinations are made without concentration if the number per cc. are over 50. Such portions are examined as will give a count of at least 20, 0.1 cc. being the least amount that should be examined. Frequent use is made of the 4.0 mm. objective in identifying species, though most of those commonly found may be classified with the objective used in counting. To examine for the species present a 2-liter sample is allowed to stand several hours in a tall bottle and a portion drawn from the bottom with a pipette; or a centrifuge is used, being run 5 or 10 minutes, and a portion taken from the bottom. Better results have been obtained with a centrifuge than by sedimentation, and its use is recommended for this work.

To obtain a fair idea of the number and species of organisms present requires four examinations; a 1 cc. portion, to obtain the number of small ones, requiring from 20 to 40 minutes; a 10 cc. portion, to obtain the number of large ones, requiring about 20 minutes; a 1 cc. portion of the settled or centrifuged sample, to determine the various small species, and a 10 cc. portion, for determining the species of larger organisms. The total time including preparation of samples is about 2 hours. If it is not desirable to know the species present in small numbers the two latter examinations may be omitted.

There is need for more work along the line of standardization of methods to be used in testing and enumerating microörganisms. The author has reluctantly departed in some instances from the methods given in the "Standard Methods of Water Analyses," American Public Health Association, for, to have comparative results, the methods of examinations should be the same.

Proposed standard volume. Considerable effort has been made to find some method whereby the volume of organisms may be more accurately determined. The standard unit is better than nothing, but it does not give an accurate estimate of the volume of organisms present. The organisms in one water may be principally small, and in another mostly large. The different seasons usually bring about changes in the microscopical growths. For some waters, notably the supply for Baltimore, the standard unit falls far short of giving a true comparison. In the late fall, winter and spring, there are frequently times when the number of standard units do not exceed the total number of organisms present, while in the summer and fall frequently the organisms are mostly crustacea and rotifera; organisms that are very large when compared with many of the algae and protozoa. Cyclops are frequently of such size as to equal in volume a cube of about 300 microns, and daphnia are not much smaller. Comparing 300 microns with 20 microns cubical size, the 20 being equal to 1 standard unit, we have a ratio of 1 to 225 standard units; but, comparing volumes, the ratio will be 1 to 3375. If there is an average of one of these organisms in 100 cc. of water, a number that is frequently exceeded in the Baltimore supply, we have 2.25 standard units per cubic centimeter, but, if compared on the basis of volume, we have 33.75 volumes per cubic centimeter; or 15 times the number of standard units.

I propose a standard of volume in which a sphere 10 microns in diameter is taken as one volume. There is great advantage in using a figure in which the movement of decimal points is all that is necessary in multiplying and dividing. Ten or 100 microns should be used. As 100 seems too large, 10 is suggested as the most convenient size. A larger percentage of the organisms is more nearly spherical or cylindrical than any other shape, and these shapes may be approximated with greater accuracy than square areas. A number of species are no larger than one proposed volume. Except for having large numbers, there is no disadvantage in using 10 microns spherical diameter as one unit of volume. There might be a slight advantage in adopting a size more nearly equal the present standard unit, but the difficulty in rapidly calculating results when variable magnifying objectives are used overcomes any advantage that there might be. The microscopical examination of drinking water in the United States is in its infancy. For the convenience of workers in the future, it is believed that the proposed standard volume will more

nearly meet their needs. The present standard unit method has the advantage that no chart is necessary, but the use of a chart as proposed is convenient and rapid. In fact, for a great many sizes of the more commonly found organisms the number of volumes will soon be memorized. The writer finds that he has to refer to the chart for only a small percentage of the organisms found.

Only two shapes have been plotted, a sphere and a cylinder based on lengths of 100 microns. If an organism is nearer spherical than cylindrical, its spherical diameter is approximated. If nearer cylindrical, its diameter and length are determined. Assume one 3 microns

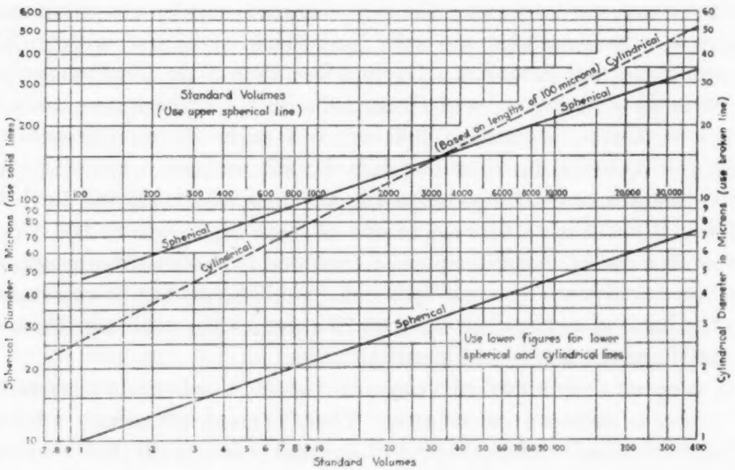


CHART 1

in diameter and 375 microns long. The chart gives approximately 1.3 volumes for a length of 100 microns, so the total number of volumes are approximately 4.9. A slide rule may be used for such calculations. There are, of course, no computations to be made for the spherical shapes.

Difficult to classify. As many of the organisms in water from a lake are dead or imperfectly formed due to unfavorable conditions for growth, it is difficult to recognize many species. The beginner usually classifies most of them under some order or genii, but after several years experience he realizes that many cannot be classified. Possibly the answer given by one worker is the way some classifications are made. "All that are motile are classified as animal organ-

isms." He was sure there were many species not pictured in Whipple's "Microscopy of Drinking Water." There is great need for a fairly complete treatise on fresh water biology. Ward and Whipple's "Fresh Water Biology" is the latest book in common use in most of the water-works' laboratories. It is an excellent book, but it does not fulfill the needs of the water-works biologist. Some of the chapters are complete, but those on algae and protozoa need revision, with more complete descriptions and better drawn illustrations. Some knowledge of biology is assumed by these authors, but this is not the case with a great many attempting to make microscopical examinations. Knowledge of chemistry is usually given preference in selecting employees for water-works' laboratories.

To meet these needs a book should contain one or two chapters on elementary biology, and if possible should have colored illustrations. Most of the illustrations of algae and protozoa described in the books mentioned show a view of one or two typical species, which might be sufficient for the expert, but not for the beginner. A better plan would be to show one or two illustrations of a typical species, using a fairly large scale, and a general outline of the other known species on a smaller scale.

The present author is unable to understand why the description of some of the schizomycetes such as crenothrix are omitted in Ward and Whipple's "Fresh-Water Biology." His experience is that such organisms are frequently found and may be erroneously classified, as they are much like Oscillatoria prolifica. If it is desirable to limit the book to its present size the chapters on tubellaria, parasitic flat worms, nemerteans, nematods and parasitic round worms could be greatly condensed. Two hundred and thirty pages are devoted to these organisms. The descriptions are excellent, but not many of these species are found in routine water examinations. They are not nearly as important to water departments as are the algae and protozoa. Part of this space could be more profitably used for more complete descriptions and illustrations of these organisms. Only 169 pages are given to the algae and protozoa, the ones most commonly found. About 500 species are described. Many more commonly found are not described. This book may not have been designed to meet the needs of the water-works biologist. If not, another one should be published.

Little attention given microörganisms. The little attention given microörganisms possibly accounts for the present lack of knowledge

and interest in them. Few water departments employ any one familiar with such work, and if they do, his duties are usually such that he can give little time to this part of the work. There should be greater recognition of the importance of this work and more highly trained workers. Water departments should not try to make biologists of chemists, nor employ as biologists men with only the ability to inoculate and count bacteria. Microörganisms are not as important as bacteria, but they should not be so neglected as they are in most departments. The usual custom of waiting until complaints of tastes and odors are numerous, before making any attempt to remedy the trouble, is frequently disastrous. Lakes and large reservoirs should be examined frequently. Preparations should be made for preventing the growths of such organisms as might cause tastes and odors or clog filters, if the water is filtered. It is frequently the beginning of the decaying stage before tastes and odors are noticeable. Killing the remaining live ones will increase the difficulty for a time.

Algae found in the Loch Raven reservoir. Systematic inspections of the Loch Raven reservoir are not made, but such inspections as have been show that several forms of algae grow in abundance in some places. The most common growths are oscillatoria prolifica, anabaena flos-aquae, aphanizomenon, closterium, spirogyra, botryococcus, ankistrodesmis, ulothrix and myxonema. Oscillatoria prolifica and spirogyra are the forms usually found in greatest abundance. Algae, as a rule, are not found in abundance along the banks in the lower parts of the reservoir, except occasionally in the early spring. This is due largely to the presence of a large number of animal organisms that feed on them.

Microörganisms found at Montebello filters. The accompanying tables and chart show the organisms found in the water coming from Loch Raven reservoir. The dates and greatest number found are given for most of them. Those marked + occur in quantities less than 1 per cc. or in quantities not determined. The numbers recorded for algae forming filaments are based on filaments 100 microns long. No classifications were made before 1920, except for a few of the most commonly found species, so most dates given are in 1920 and 1921. Since greater care was taken with the work in 1921, the largest numbers found that year are given in most cases.

Decaying algae clog filters. Every summer great quantities of partly decayed algae growths rapidly clog the filters. At first it was thought the short filter runs were due to crustacea, daphnia, bosmina

and cyclops being found at times in great numbers. Later, however, this was found to be due largely to the decaying and breaking up of algae growths. Crustacea are usually found in greatest numbers at times of abundant algae growths, for the algae furnish the necessary food. As 15 per liter is the greatest number found going on to the filters, and many of that number keep swimming, it is evident they are not the sole cause of the rapid clogging of the filters. At times of short filter runs, the raw water has a considerable amount of amorphous matter, sometimes called a gelatinous colloid, varying in size from 5 to 200 microns in diameter. This is caused largely by the

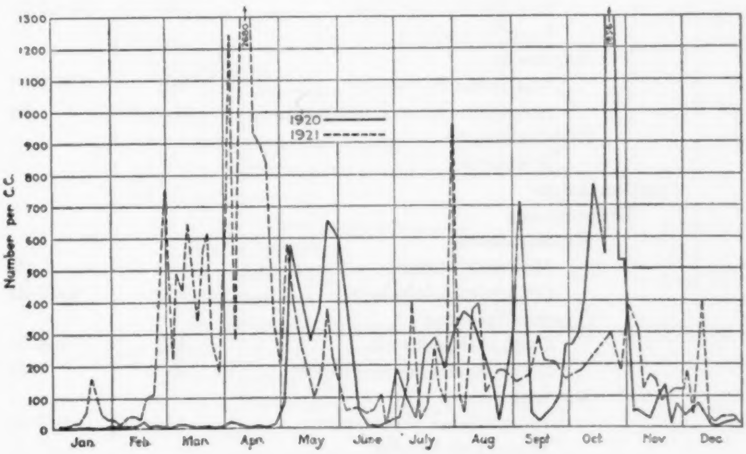


CHART 2

decaying algae growths. This gelatinous amorphous matter is much tougher than the coagulant formed by alum, and does not penetrate the filter beds to as great a depth as does the floc due to coagulation. At such times it is difficult to filter 250 cc. of the sample through the sand in the Sedgwick-Rafter filter used in concentrating the samples, as the amorphous matter rapidly forms an almost impervious layer on top of it. Frequently this condition occurs when there are only one or two crustacea present, and the other microörganisms are few in number. There are times, however, when the clogging may be attributed partly to the live organisms.

When amorphous matter is absent, or only in small quantities, the floc formed by adding a coagulant penetrates the filter beds to con-

TABLE 1

Microörganisms in water from Loch Raven reservoir before treatment. Vegetable organisms

KINGDOM / GROUP / CLASS / ORDER / FAMILY / GENUS	GREATEST NUMBER FOUND PER CC.	DATE
Vegetable		
Algae		
Cyanophyceae		
Coccogoneae		
Chroococcaceae		
Coelosphaerium	+	21
Hormogoneae		
Oscillatoriaceae		
Oscillatoria prolifica	285	12-10-21
Lyngba major	+	20
Nostoceae		
Anabaena flos-aquae	100	8-1-17
Aphanizomenon flos-aquae	+	21
Rivulariaceae		
Rivularia	+	21
Bacillariaceae		
Diatomaceae		
Melosiraceace		
Melosira varians	+	20
Orthosira orichalcea	140	4-12-21
Coscinodiscaceae		
Cyclotella compta	462	4-8-21
Stephanodiscus niagareoe	+	20
Naviculaceae		
Pleurosigma attenuatum	14	8-9-21
Pinnularia viridis	+	4-12-21
Navicula rhynchocephala	84	5-3-21
Stauroneis anceps	28	5-6-21
Cymbellaceae		
Amphora ovalis	+	21
Cymbella cuspidata	1	12-27-21
Encyonema	112	5-6-21
Nitzschiaceae		
Nitzschia	500	17
Surirellaceae		
Surirella	1	8-2-21
Meridionaceae		
Meridion	+	20
Fragilariaceae		
Synedra	28	4-5-21
Fragilaria	28	4-8-21
Asterionella gracillima	1,700	10-22-20
Tabellariaceae		
Tabellaria	+	20

TABLE 1—*Continued*

KINGDOM / GROUP / CLASS / ORDER / FAMILY / GENUS	GREATEST NUMBER FOUND PER CC.	DATE
Chlorophyceae		
Conjugales		
Desmidiaceae		
Hyalotheca dissiliens	+	21
Closterium moniliferum	2	5-13-21
Zygnemaceae		
Spirogyra	+	21
Protococcales		
Volvocaceae		
Endorina elegans	140	5-3-21
Palmellaceae		
Botryococcus braunii	+	21
Sphaerocystis	+	21
Chlorellaceae		
Lagerheimia genevensis	1	4-26-21
Ankistrodesmus	1	6-3-21
Tetraedron	1	6-28-21
Coelastroceae		
Scenedesmus quadricauda	1	21
Confervales		
Ulothrichaceae		
Ulothrix zonata	+	21
Chaetophoraceae		
Myxenon lubricium	10	4-19-21

siderable depths. Part of it begins to pass through with various losses of head from about 2 feet to 8 feet. If it is present in large quantities there is little penetration, and the losses of head rise rapidly to the maximum on all filters. We expect naturally the most amorphous matter in times of low turbidity. This is the case, and consequently the most rapid rise in loss of head occurs in the filters. They sometimes go from 1 foot, just after washing, to 8 feet in about 12 hours. A sudden change, due to heavy rains, will wash out and dilute the amorphous matter to where there is very little left, and, with the same turbidity going on to the filters, the lengths of run may change from 12 hours to 75 or 100 hours. At no time during high turbidity, or of low turbidity, when amorphous matter is absent, does the loss of head through the filter beds rise as rapidly

TABLE 2

Microörganisms in water from Loch Raven reservoir before treatment. Animal organisms

PHYLA / SUB-PHYLA / CLASS / ORDER / FAMILY / GENUS	GREATEST NUMBER FOUND PER CC.	DATE
Protozoa		
Sarcodina		
Rhizopoda		
Testacea		
Arcellidae		
Arcella vulgaris	+	20
Difflugia urceolata	+	20
Difflugia pyriformis	+	20
Difflugia	1.3	11-25-21
Cucurbitella	+	8-2-21
Euglyphidae		
Pamphagus	+	20
Gymnamoebida		
Amoebidae		
Pelomyxa palustris	+	8-4-21
Actinopoda		
Aphrothoracida		
Actinophrys sol	2	6-14-21
Mastogophora		
Zoomastigophora		
Monadidae		
Rhizomastigidae		
Mastigamoeba	+	21
Crecomonadidae		
Crecomonas	+	21
Bikoecidae		
Stylobryon	+	20
Euglenida		
Euglenidae		
Euglena	21	3-28-21
Trachelomonas	4	1-10-21
Phacus longicaudus	+	20
Astasiidae		
Astasia trichophora	2	1-13-21
Distigma proteus	+	20
Phytomastigophora		
Crysoflagellida		
Mallomonas	1	6-5-21
Chilomonas	+	20
Uroglena americana	3	8-12-21
Synura uvella	+	20
Dinobryon sertularia	1	6-22-21

TABLE 2—*Continued*

PHYLA / SUB-PHYLA / CLASS / ORDER / FAMILY / GENUS	GREATEST NUMBER FOUND PER CC.	DATE
Chloroflagellida		
Volvox	+	20
Peridinium tabulatum	+	20
Ceratium hirundinella	0.1	6-7-21
No. 3	112	8-23-21
Infusoria		
Cilliata		
Holitricha		
Trichoda	+	20
Lexocephalus	+	20
Paramoecium	+	21
Cyclidium	+	20
Ctedoctema	1	11-25-21
Heterotricha		
Halteria	.1	4-5-21
Peritricha		
Epistylis	.1	6-3-21
Vorticella companula	1	6-3-21
Suctoria		
Dendrosoma radians	1	8-9-21
Trochelminthers		
Rotatoria		
Notommatida		
Notommatidae		
Nottommata aurita	+	21
Synchaetidae		
Synchaeta tremula	.2	4-19-21
Polyartha platyptera	.7	5-6-21
Anuraeidae		
Anuraea cochlearis	1.0	11-8-21
Eretmia trithrix	.1	4-19-21
Melicertida		
Pedalionidae		
Pedestes saltator	.1	8-23-21
Triarthra longiseta	.7	5-3-21
Tetramastix opoliensis	.1	8-2-21
Pedalion mirum	.2	8-16-21
Melicertidae.		
Conichilus unicornis	.6	6-22-21

TABLE 2—*Concluded*

PHYLA / SUB-PHYLA / CLASS / ORDER / FAMILY / GENUS	GREATEST NUMBER FOUND PER CC.	DATE
Arthropoda		
Crustacea		
Calyptomera		
Daphnidae		
Daphnia	.05	6-6-21
Bosminidae		
Bosmina	.05	6-6-21
Copepoda		
Cyclopidae		
Cyclops	.20	6-22-21
Hexopoda		
Diptera		
Culicidae		
Corethra (larva)	.0003	21
Tentaculata		
Bryozoa		
Gymnolaemata		
Paludicella eherenbergi	2.0	8-10-21
Phylactolaemata		
Pulmatella polymorpha	+	8-5-21
Pectinatella magnifica	+	8-24-21
Coelenterata		
Hydra	.001	8- 5-21
Porifera		
Tubella	1.0	8-2-21
Spongilla	+	8-5-21
Nemathelminthes	+	21

as when it is present. Filters are not allowed to run to their maximum, if coagulated particles pass the beds, and are washed at losses of head varying from 2 to 8 feet. When amorphous matter is present in large quantities, they will almost invariably run to their maximum without passing coagulated matter.

Effects of microörganisms on bacteria. In the warmer months, the sunlight and animal organisms keep the bacteria in the raw water at a low number, except in times when the turbidity is above the average and the animal organisms are not numerous. This is clearly shown by storing samples of raw or filtered water in a place favorable for bacterial growth and unfavorable for microörganisms. The bacteria

will increase rapidly in large numbers, continue for a short time, then gradually decrease, until the water will be almost free of them in a few months. This shows that the water has the necessary food for bacterial growth, only awaiting favorable conditions. It is doubtful if the enormous increase in bacteria frequently noted in reservoirs, after treating with copper sulfate, are all due to decaying organisms furnishing the food for their growth. They do furnish some of it, but most spring water, free from microörganisms, if allowed to stand in a place favorable for bacterial growths, will show a great increase.

We find at certain times, when turbidity is low and the water comes largely from springs, when microörganisms are abundant and the bacteria few, that water passing the filter beds will show an increase in bacteria, notwithstanding the fact that many present in the water going to the filters are filtered out. The water is chlorinated as it enters the clear water reservoir and the bacteria are reduced to about 5 per cc., also killing practically all the microörganisms that pass the filter beds. The chlorine is applied in quantities that will give a residual of about 0.10 p.p.m., leaving the clear water reservoir, which is about four hours after application. This extends over most of the distribution system, gradually decreasing, until there is none in the outlying sections. There is no increase in bacteria as long as residual chlorine is present, but in the outlying sections where there is no residual, bacteria increase in large numbers in the warmer months. Judging water by its bacterial content, it is evident that microorganisms which feed on them are helpful, but the difficulty in handling such organisms in large numbers and the possibility of tastes and odors will overcome probably any benefit that might be derived from their presence.

Microörganisms passing filter beds. A large percentage of motile organisms pass through the filter beds, but most of them are readily killed by the chlorine, as the water leaving the clear water reservoir is almost entirely free from such organisms. Examinations of the water after filtration and before chlorination have not been made regularly, but, during 1920, this work was carried on for a period of several months with the same frequency as the raw water. They are greatly reduced in the settling basins, but as no tests are made at this point, we may only compare the filtered water with the raw water, as shown in the following table:

DATE 1920	MICROÖRGANISMS PER CC.							
	Algae		Protozoa		Rotifera		Crustacea	
	Raw	Filtered	Raw	Filtered	Raw	Filtered	Raw	Filtered
July	3.8	0.0	119.3	8.9	0.8	0.3	0.07	0.03
August	2.3	0.0	216.9	30.6	0.2	0.04	0.04	0.004
September	29.8	1.0	148.7	20.3	0.7	0.3	0.13	0.03
October	405.7	2.0	160.6	30.8	0.4	0.2	0.07	0.02

Decaying organisms increase the bacteria in winter months. During winter, when the reservoir is frozen over, there are places along the edges where the water circulates little, if any, and the algae growths gradually decay. While the temperature is below that usually regarded as necessary for bacterial growths, they do grow, possibly very slowly, to where they are present in large numbers. When the ice breaks up, bacteria may be found in the raw water in numbers as high as 500,000 per cc. The release of all this decayed matter usually produces bad tastes and odors. There is always considerable increase in bacteria after heavy rains when the water is turbid, but in winters when there is practically no ice, the number is not nearly as high as when there is a severe winter. Comparing the counts in the winter of 1917–1918, a very severe one, with 1918–1919, a mild one, the difference is readily noted. In a mild winter, the decaying algae growths are not held at the place where decay is taking place, but they gradually mix with the balance of the water from day to day, and prevent any great accumulation of bacterial growths.

DATE	TURBIDITY	BACTERIA PER CC.	
January 18, 1918	100	475,500	Severe winter
January 31, 1918	23	418,000	Severe winter
January 2, 1919	135	10,250	Mild winter
January 30, 1919	68	36,000	Mild winter
February 1, 1919	68	21,000	Mild winter

These counts are the highest, but the averages are in somewhat the same proportion. Every analysis points to decaying algae as the main cause of the difference.

Copper sulfate not used. Copper sulfate has not been used to prevent algae growths in the Loch Raven reservoir, although the writer has advised its use several times. There is a large amount of silt in the water at times of high turbidity. A great deal of it settles in the upper part of the reservoir, when the flow is checked, resulting in a broad area too shallow for row boats and too soft for boots. It would be difficult and expensive to apply copper sulfate properly in this area, and for this reason no attempt has yet been made. It is not believed that any good may be accomplished by applying it just before filtration, for it will not have any effect on the amorphous matter, and crustacea are not killed with doses that may be safely used. Only a small percentage of the crustacea are killed when 10 p.p.m. are applied. The writer believes it is worth the expense of keeping algae growths in check in any reservoir used for drinking water, which will also keep the animal organisms in check. Bad tastes and odors are not pleasing to any one, and when they occur frequently, they result in the use of spring water, if any is available. Just how much pure and palatable water will prevent the use of spring water, we are unable to say, but there are many thousands of dollars spent for it every year in Baltimore.

Microörganisms increase chlorine tastes. Before the use of chlorine, few of the organic compounds produced by microörganisms caused odors or tastes, but evidence indicates that these troubles have been greatly increased by its use. When water comes from large reservoirs, the organisms present in the effluent may give no indication of the ones actually causing the trouble. It is only by systematic inspection of the reservoirs and the water sheds that definite information may be obtained. We know that frequently the application of small amounts of chlorine produce disagreeable tastes, and, at other times, several times the same amount will not. Some change of the soluble compounds in the water are probably responsible for the trouble. Many supplies are derived from sources that receive no pollution of any kind, yet the application of chlorine in moderate amounts frequently will produce tastes. Experiments on adding a small amount of water from samples having an abundance of algae growths to larger samples of distilled and tap water, and treating with chlorine, give more noticeable tastes than the same amount applied to water that has not been mixed with the water containing the algae growths. There is need for carefully conducted tests to determine the relation of tastes and odors to the various common

organisms, when the water is treated with chlorine. Some species of algae and protozoa apparently produce no tastes. Others may produce disagreeable tastes, even though chlorine is not applied. Between these extremes, it is believed there are many microörganisms that will not produce noticeable tastes or odors if chlorine is not applied to the water, but when it is applied disagreeable results occur.

Soil stripping of reservoirs not necessary. We are unable to find any evidence that stripping reservoirs of the top soil, or even removing the stumps, warrants the expense where water is afterwards filtered. Several years ago the water level in the reservoir was raised 4 feet, covering considerable shallow areas, and as far as could be detected, there was no change in the quality of water or the number of microorganisms, although careful tests were not made regularly. The enormous algae growths frequently occurring in spring water, which comes in contact only with stone, sand, or gravel, show clearly that water usually contains the mineral and organic matter necessary for algae growths.

There is great advantage in eliminating shallow areas, especially where aquatic plants may grow, but it is doubtful if it is worth the expense of excavating a fairly steep shore line where these areas do occur. Logs, branches of dead trees, and other trash have collected at times in some of the coves. Yet there is no evidence of any greater accumulation of algae growths at such places than would have naturally occurred. The dam forming the Loch Raven reservoir has recently been raised to form a storage reservoir of over 20,000,000,000 gallons. The filling of the reservoir was started in April. With the exception of clearing away the trees and underbrush, nothing else has been done and it is believed there will be no noticeable effect on the water.

FIRE PREVENTION AND FIRE PROTECTION IN RELATION TO THE PUBLIC WATER SUPPLY[1]

By Frank C. Jordan[2]

America's fire loss has reached the proportions of a national calamity and we are becoming a criminally careless people. Burning four or five hundred million dollars worth of property every year has ceased to be a matter of no concern. Our increasing fire loss stands as a serious indictment of the American public. Our 1921 fire loss means that five hundred million dollars worth of natural and created resources are wiped out of existence. There is a prevailing opinion that fire insurance companies in some mysterious way make good our loss by fire. The proceeds of a fire insurance policy may reimburse the individual for the loss he has sustained, but no amount of money can restore a burned structure. When a fire occurs everybody loses.

During the World War, we were bitter in our denunciation of the German nation by reason of the wanton destruction of thousands and thousands of acres of French forests by the German army. Our papers gave picture after picture depicting the burned and damaged forests, and we took a vow that Germany must be made to pay for this damage. In the year 1921, American forests were burned equal in acreage to eight times the total acreage destroyed or damaged in France during the four years of the World War, and 75 per cent of all of our 1921 forest fires were due to human agencies and could have been prevented by care and vigilance on the part of forest users. Sufficient timber was burned in American forests last year to build 5-room houses for the entire population of such cities as Kansas City, New Orleans, Washington, Seattle, Portland, Rochester or Indianapolis. America's fire loss during the year 1921 exceeded five hundred million dollars, this amount covering insurable property only and not including loss of forests, standing grain, pasture lands, etc. Mr. H. A. Smith, President of the National Fire Insurance Company of

[1] Presented before the Philadelphia Convention, May 16, 1922.

[2] Secretary, Indianapolis Water Co., Indianapolis, Ind.

Hartford states, in an article appearing in the *New York Journal of Commerce*, that disbursements by the insurance companies during 1920, covering losses and operating expenses, exceeded the losses and expenses for any other year in the history of our country with the exception of the year 1917. These figures also show that the amount paid out by the insurance companies in the year 1906, the year of the San Francisco fire, totaled $359,642,372. We remember well that the fire loss for that year was a serious shock to many of our great financial institutions and that it caused great concern all over our country. The losses and expenses for the year 1920 exceeded the 1906 insurance figure by one hundred and five million dollars. Generally speaking the public concerned itself very little about the matter.

A comparison of the fire losses for the years 1906 and 1920 gives us an interesting picture of the workings of the public mind.

The actual fire loss on created property in 1906 was $459,710,000, an amount $129,000,000 greater than the loss on created and insured property in 1920. Much of the San Francisco property carried little or no insurance, the insurance companies paying out only $359,000,000 during the year 1906. The public, therefore. had first hand knowledge of the terrible ravages of fire and great was the clamor for fire prevention. This enthusiasm wore off in a short time and the public apparently contented itself by covering its property with an insurance policy and forthwith passed the burden of worry to the insurance companies. In 1920, with a fire loss of $330,000,000 on created and insured property, the insurance companies paid out $464,000,000 covering fire loss and operating expenses. Having only second hand information in regard to the ravages of fire, the public did not greatly concern itself.

A careful survey seems to indicate that the only answer which our country makes to this ever increasing fire loss is to add largely to its insurance premiums and to its fire departments, both in men and equipment. Today our fire departments are recognized as the most efficient in the world and well they need be. American travelers to foreign lands are prone to make rather uncomplimentary and facetious remarks in regard to the antiquated fire fighting epuipment maintained by the European cities, entirely overlooking the fact that, while we have been busily engaged in increasing the efficiency of our fire fighting equipment, the American public has been even more busily engaged in increasing its careless habits. We are today confronted with the lamentable fact that our country, with all of its

wonderful development and fire fighting force and equipment, has an annual fire loss of almost $5.00 per capita, whereas the foreign countries, with antiquated fire fighting equipment, but with careful habits reinforced by severe personal liability laws, have an annual per capita fire loss ranging from 11 to 60 cents.

The depletion of our resources by fire is in itself an exceedingly serious matter, but the seriousness of the financial loss is greatly exceeded by the seriousness of our loss of life due to fire. Our 1920 figures show that 15,219 persons were burned to death in the United States and 17,641 were seriously injured. Eighty-two per cent of the dead and injured were mothers and children, and 92 per cent of the fires that caused these fatalities were the result of carelessness or negligence. Carefully prepared statistics indicate that approximately 80 per cent of all the fires occurring in the United States are preventable.

In view of our appalling loss in life and property, it is imperative that all great organizations, such as the American Water Works Association, give most careful attention to the question of fire protection and fire prevention and exert every effort to bring about the elimination of all of those fires which are classed as preventable. It is high time that we turn the spotlight of publicity on our fire loss, make a careful study of the causes of our fires and map out a carefully prepared campaign of education, to the end that the right-thinking people of this country may understand the seriousness of our fire loss and take proper steps to cut this loss to a minimum figure. This campaign of education should be followed by the enactment of rigid laws covering personal liability for preventable fires, and these laws should be enforced to the letter, so that the irresponsible or evil-minded citizen will be compelled to eliminate preventable fires. It has been truly stated that a man who has a preventable fire picks the pockets of his neighbors, either through the medium of fire insurance or an unjustified use of the public fire department which all must support. It is equally true that the fire departments are not maintained to protect a man from the results of his negligence. When he calls upon the city in any such case he should be made to pay for this service. No civilized country should expect its firemen to risk their lives in fighting fires which are easily preventable. In many of the foreign countries, a man who has a fire must prove to the court that he was in no way responsible for the fire or he is subjected to a fine and the loss of his insurance. The time must come when the

United States will enact laws covering personal liability for preventable fires.

The public conscience has become dulled to the necessity for any fire prevention measures. We feel relieved when we read the words "fully covered by insurance." We feel that some soulless corporation called an insurance company will shake a tree bearing a never ending crop of dollars and gather up this money and hand it to the insured, fully compensating him for all loss. We overlook the fact that our tremendous fire loss, plus the cost of operating insurance companies, is borne by all of us in the way of insurance premiums and that this amount constitutes one of our greatest national expenditures. Only a few years ago the average insurance agent took little interest in the subject of fire prevention, the fact of an increase in fire loss being used by him as an argument to his clients to take out more insurance. The progressive insurance agents of today, however, take a different view of the matter. President F. J. Fox of the National Association of Insurance Agents gives voice to the following statement: "Although it may seem to the shortsighted agent poor business to recommend to an insured that if a certain pile of rubbish is disposed of, the rate can be reduced from $1.25 to 13 cents, as a matter of fact such advice is a part of the duty every agent owes to his clients even though such advice may reduce the actual premium rate involved." He further states that: "It is a notable fact that the press of the country has been active in aiding communities to reduce their fire losses, and it is absolutely essential that reputable agents throughout the country co-operate with every ounce of energy to the same end."

No organization in the United States should be more interested in the subject of fire protection and fire prevention than the American Water Works Association. I sincerely trust that this Association will at once go on record, pledging its unqualified support to any movement looking to the curtailing of our fire loss. I desire to speak a word in commendation of the fine service which is being rendered by the National Fire Protection Association, and to enlist your support of that organization. Through the distribution of carefully prepared literature, and the putting forth of unstinted efforts in the cause of fire prevention, it is rendering a nation-wide service, the value of which cannot be measured in dollars and cents. I should be glad to see our Association affiliate with the N. F. P. A., and it seems to me that it would be wise for our Association to urge all of its members to join the N. F. P. A. and co-operate with it in every way in the great campaign of fire prevention.

If the fire prevention program is to be successful, it will be due in no small measure to the co-operation on the part of the water plant superintendent. His first duty will be to see that his property is fully equipped to furnish adequate fire protection service. This may require the expenditure of a considerable amount of money, but the value of the adequate fire protection service will far outweigh fixed charges on the extension and additions necessary to bring the plant up to a point where it can furnish excellent service. The Committee on Fire Prevention and Engineering Standards of the National Board of Fire Underwriters of New York has made a large number of reports on the water departments of the country. If their suggestions are carried out these water departments would be in position to furnish excellent service and we should to the fullest extent co-operate in the fire prevention program. During the past fifteen years, the National Board of Fire Underwriters has made several reports on the Indianapolis Water Company's property. We have found these reports exceedingly valuable, in that they have pointed out our weak spots and have guided us in mapping out our future extensions and additions. Our Company is making a conscientious effort to comply with all of their suggestions, and it is our opinion that the increased efficiency of our water service has justified our expenditures. On a number of occasions they have modified some of their requests or requirements after getting our viewpoint. In all of our dealings with the representatives of this organization, we have found them broad minded and fair. I trust that there may be the finest spirit of co-operation between all of our members and the National Board of Fire Underwriters, so that the water plants over the United States may furnish a thoroughly satisfactory fire protection service. A high fire loss in a city raises a question as to the integrity of the water plant to the same degree that a high typhoid rate raises a question in the minds of the people as to the purity of the water supply. These assumptions on the part of the public are not entirely true, but nevertheless they exist in the minds of many or our citizens. Years of patient effort have largely eliminated typhoid fever. The same patient effort will eliminate our preventable fires.

The up-to-date water works official made every effort to eliminate typhoid, and he should work just as hard toward the elimination of preventable fires. If a fire prevention campaign has been inaugurated in his city, he should co-operate with it. If none has been inaugurated, he should initiate one and do his utmost to carry it through to suc-

cessful conclusion. Acting on this assumption, and on the invitation of Mr. W. J. Curran of the Indianapolis Salvage Corps, and E. M. Sellers, Manager of the Indiana Inspection Bureau, the writer suggested to the Indianapolis Chamber of Commerce the formation of a Fire Prevention Committee. This was done in the early part of April, 1921, and the writer was made Chairman of a Fire Prevention Committee consisting of about 1,200 Indianapolis citizens. At the outset, we made a most careful study of our fire loss and were amazed to find that it had increased from a per capita loss of $1.75 in 1910 to a per capita loss of $5.10 for the year 1920, and that the average Indianapolis citizen had increased his careless habits in a greater ratio than the City had been able to increase its fire fighting facilities. Our investigation showed that in the year 1910 our city had 5.8 fires per thousand population, and that this had increased to 10.7 fires per thousand population during the year 1920. After going into this matter with great care, we determined that this great fire loss could not be checked by any campaign of one week or one month's duration. When our campaign was launched we went into it determined to spend four or five years, if necessary, to achieve the results for which we were working, namely, a cleaner and healthier Indianapolis with an exceptionally low fire loss. We realized that the sucess of our undertaking depended almost entirely upon the one word, "Co-operation." I am pleased to report that we have received as fine a spirit of cooperation as has ever been accorded to any city-wide undertaking in the City of Indianapolis.

At the outset of the 1921 campaign, the City evidenced its interest by defraying the expenses of the Fire Prevention Campaign, and during the 1921 Campaign, and the same will be true of the 1922 Campaign, not one dollar has been put up by any one who might in any way be interested from an ulterior motive. The Fire Department, and in fact all City Departments, have co-operated in an exceptionally fine way and have done their utmost in the cause of Fire Prevention. No finer service has been rendered by any one than that rendered by the public and parochial schools, and a large measure of the success of our campaign has been due to the exceptionally fine co-operation accorded by these organizations. Through the instrumentality of thousands of fire prevention essays, programs and many, many talks by teachers, the subject of fire prevention is being taught to the younger generation. It is our firm conviction that within a few years a careless people, and a consequent high fire loss, will be un-

known. The churches, sunday schools, and civic clubs have at all times taken a lively interest in the subject of fire prevention and have given much publicity to our campaign. The Board of Sanitary Commissioners took upon its shoulders the burden of removing all rubbish, or any refuse of any kind which had accumulated around the homes. Two hundred and fifty thousand pieces of fire prevention literature were distributed, and fire prevention cards are still hanging in thousands of Indianapolis homes. Added to this co-operation from the city officials, schools, clubs etc., was the exceptionally fine co-operation from citizens in general. The net result of all of these efforts during 1921 was a great decrease in our fire loss and a surprisingly large decrease in our loss of life. Our 1921 fire loss showed a decrease of $550,000, as compared with 1920. From April 1, 1921 to the present time but one person has been burned to death in our city instead of our usual annual loss of from 12 to 20. The greatest result, however, of our 1921 Fire Prevention Campaign, was the laying of the foundation for a greater fire prevention effort. Our 1922 program holds promise of even greater success than was attained in 1921.

Generally speaking, our 1922 campaign is divided into five separate and distinct campaigns, namely:

"Let's Clean 'Er Up" Campaign, running from April 3 to April 29.

Fire Resistant Roof Campaign, April 12 to May 13.

City Beautification Campaign, May and June, closing with the awarding of prizes on June 15.

Clean-Up and Fire Prevention Publicity Campaign, October, 2 to October 16.

No Accident; No Fire Week, November, 1 to November 8.

After mapping out our 1922 program, we received a pledge of active co-operation from the new city administration, and I am pleased to report that the Mayor and every department of his administration are giving unqualified co-operation. The City Council appropriated funds and our program was launched with the assurance of city-wide support. We distributed a large amount of "Let's Clean 'Er Up" literature, and the newspapers gave much space. As a net result our city has experienced the best clean-up in its history. Inspectors from the fire and police departments inform us that they are finding it necessary to serve but very few official clean-up notices.

During the months of January and February of this year, our city had occasion to realize the absolute necessity of the elimination of the shingle roof, which according to our Fire Chief is our greatest fire

hazard. We have approximately 60,000 buildings covered with wooden shingle roofs, and during the first two months of this year we had 850 shingle roof fires, the maximum number for any one day being on February 16 when we had 63 fires, every one of which was due to a defective flue or sparks on a shingle roof. We have at this time a city ordinance which prohibits the use of wooden shingles on new buildings, and provides further that if 50 per cent of a roof is damaged the entire roof must be replaced with a fire resistant roof. This ordinance, however, fails to specify a time when all shingle roofs must be replaced with fire resistant roofs, and the change is therefore very slow. A great many of the cities over the country have rigid ordinances in reference to shingle roofs, and the value of these ordinances will be realized when we compare our record of more than 1,200 shingle roof fires in 1920 with a record of New Orleans where there were 24; Cincinnati 56; Louisville 110; St. Paul 99 and Philadelphia 110. We held a large number of conferences with the Indianapolis roofers and explained to them that, if our campaign to eliminate the wooden shingle roofs was successful, it would be because of the coöperation of the roofers, and that in order to coöperate it would be necessary for them to do three things:

1. Educate the public to the fact that good roofing in an asset, whereas, inferior roofing in a liability.
2. Put on good roofing at a fair price.
3. Put on good roofing on the payment plan.

I am very glad to say that practically all of our roofers are coöperating in a fine way and have assured us that they would do everything in their power to further this program. We carried some publicity in our papers in the latter part of March in reference to the absolute necessity of eliminating the wooden shingle, and prepared to launch a strenuous campaign from April 12 to May 10. The public, however, beat us to the proposition and roofers in Indianapolis tell us that they have all the work which they can possibly handle for some time. Our Building Commissioner is issuing from 35 to 60 re-roofing permits every day, and more will be issued later on when we get more roofers on the job.

We are arranging to conduct a city beautification campaign on the theory that, if we can replace a rubbish pile with a flower bed or vegetable garden, there will not be much liability of another rubbish pile growing on or near that place. In other words, we hope to make a geranium or tomato grow where rubbish formerly flourished. We

are perfecting an organization in every ward with two chairmen, a man and a woman, and 200 or more ward workers. Our plans contemplate a yard beautification contest with fifteen or more prizes for each ward and 800 certificates of merit to be distributed throughout the city. Approximately one-half of the prizes and certificates of merit will be awarded for the best yards, and an equal number for the yards showing the greatest improvement. In addition to the ward prizes, we will have 15 to 25 major prizes to be awarded by the Mayor for the most beautiful lawns and premises in the city. We are availing ourselves of the services of the Park Department, City Planning Commission, Board of Sanitary Commissioners, and in fact, all city departments having to do with the general appearance of our city. The foundation is being laid for a city-wide effort which should, within the near future, make our city one of the beauty spots of the country.

In the fall, we will have a Clean-Up Campaign and a Campaign of Education in regard to fire prevention measures. This will be followed by a "No Accident; No Fire Week" in November.

Our Committee on Laws and Ordinances is giving careful attention to the preparation of a City Ordinance making rigid provisions for the elimination of the shingle roof, and is also preparing a bill for presentation to the next Legislature covering Personal Liability for Preventable Fires. We are just beginning to realize the length and breadth of a fire prevention program. Our experience indicates that it achieves the following results for a City:

1. Makes for better health conditions through the instrumentality of clean-up programs.
2. Decreases fire loss.
3. Decreases the loss of life due to fire.
4. Is essentially a safety first campaign.
5. Makes a city beautiful through the elimination of rubbish piles, dilapidated buildings and other fire hazards; and
6. Makes better American citizens.

Our neighboring city, Cincinnati, has achieved wonderful results through the instrumentality of its fire prevention campaign, which has been waged unremittingly for the past several years. Their records show a reduction in fire loss of more than one and one-half million dollars a year, a reduction of 20 fire houses, with a consequent reduction in taxes and an insurance rate which is said to be the lowest in the United States. What Cincinnati has done, Indianapolis can do, and what we can do every American city can do.

In order to get this matter before the Association in concrete form, I desire to present the following preambles and resolutions and move their adoption:

WHEREAS, America's fire loss has reached the proportions of a national calamity and as a nation we are becoming criminally careless; and

WHEREAS, The United States and Canada are suffering from economical impoverishment due to excessive annual losses of their created and natural resources from preventable fires; and

WHEREAS, Proper fire prevention and extinguishment is a subject closely related to and affecting the competent conduct of the waterworks systems of the states, provinces and municipalities of these countries;

It Is Therefore Resolved, That the American Water Works Association pledges its active interest in furthering and participating in all proper efforts to reduce the fire losses of these countries and calls upon its members actively to initiate, assist and encourage in their various localities movements to this end.

I would further move that the American Water Works Association co-operate with the National Fire Protection Association and that effort be made to induce our members to join the National Fire Protection Association.

I would further move that the American Water Works Association call upon all of its members to co-operate with the National Board of Fire Underwriters to the end that each water plant may furnish adequate fire protection service.

DISCUSSION

ALLEN HAZEN:[3] This is one of the most important subjects for us to consider. Mr Jordan has presented it admirably. He spoke of the conditions in America as compared with the conditions in Europe. I have made that comparison. I am much interested in it and I intended to tell you a lot about it, but I am not going to. You do not have to go to Europe to get the comparison. Only a few miles from our shores, Havana, a city as large as New Orleans, is practically free from fire losses. Insurance is practically unknown there. I see some of our members here who know Cuban conditions and can tell you about that. During the war I was asked by the President of the Cuban Republic to examine the water supply of Havana and see what it needed. The first thing I found was that there was no fire protection whatever. The pipes are not laid out for fire protection, they are laid out for distribution only. They are barely big enough for that.

[3] Consulting Engineer; Hazen, Whipple and Fuller, New York, N. Y.

There is no fire protection in the pipe system of Havana. There is one fire house in Havana, built by the Americans because it looked rotten to see the city of Havana without a single fire house, so it stands there on one of the principal streets carrying the name of the second American governor. I do not know that it was ever used. In all the time I was there, I never saw anything happen to that house. It is there as a monument to American operations. I think Mr. Jordan will find that after his shingle roofs have gone the next step, in the central part of the city at least, will be the wooden floors. I think they will follow the shingle roofs , as they did in Havana fifty years ago. You will see in Havana a beautiful city as large as New Orleans, 400 years old, and which, in that 400 years, has not had a destructive fire.

I have just received from Camaguey, Cuba, one of the important cities of the island after Havana, a letter dated May 11, in which the writer, J. Garcia Montes, Jr., states in regard to fire draft:

"It was consequently left out of consideration in averaging, because of the fact that fires take place in Camaguey at the rate of two in ten years."

LEONARD METCALF:[4] After listening to this admirable paper of Mr. Jordan's, it occurred to me that it might be interesting to say just a personal word in regard to his work. This is the work essentially of a waterworks man; it is due to Mr. Jordan's enthusiasm and the way in which he was able to inspire confidence, in the Chamber of Commerce, the city officials and the good citizens of Indianapolis. Unsought by him, the Mayor, having that degree of confidence, offered him a fund of something like $2,000 to take up the initial work incident to this investigation, to enable him to visit different cities in this country, study their methods of fire fighting, get in touch with the underwriters, and through his interest and energy the underwriters took the thing up actively, sent representatives to Indianapolis, who put their fire department, I believe, through a course of stumps and made suggestions which were of great value to them. Through his interest and activity the Chamber of Commerce came to play an active part and has inspired the confidence of the men of means of the community who were ready to go down into their pockets to further the work. The thing of significant interest, it seems to me, to this organization, is that his work can be duplicated by many

[4] Consulting Engineer; Metcalf and Eddy, Boston, Mass.

of you men, and this organization is in a position to help you in that work. Of course, Mr. Jordan will be glad to help you and tell you what he found best while in his investigations. If such a work could be taken up by even a handful of men of this organization and produce such results as Mr. Jordan has been able to get in Indianapolis, it would be of immense advantage to this country.

J. N. CHESTER:[5] As others have said, I think this paper is a magnificent one. I have all along been handing Jordan the palm as the chief propagandist for water companies. It is on this subject that I want to say a few words, especially to the privately owned waterworks superintendent. Do any of you here think, after hearing this paper and seeing what Mr. Jordan has accomplished in Indianapolis, do any of you suspect for a minute that that waterworks superintendent is not in good standing in his community? That his word is ever doubted? That they are finding fault with the waterworks and looking down upon them? I lived in Indianapolis in the day when I do not think the waterworks superintendent stood as high in the community as we know Mr. Jordan stands today. It is probably not all due to the good services he has rendered, but to the interest he has taken in civic affairs and what he has done for the public generally that has put him not only at the top of the list as a private waterworks superintendent, but heading the list of public spirited citizens in that community.

D. R. GWINN:[6] In addition to the work Mr. Jordan has done in Indianapolis, he has been going up and down the state holding meetings for the extension of fire protection work. He came to our city some time ago, addressed the luncheon of the Chamber of Commerce and had a fine audience that listened to what he had to say with a great deal of interest. I am sure they are going to take up the work Mr. Jordan started in Indianapolis. He has been to Evansville, Terre Haute and Fort Wayne and has started these campaigns in other cities. We have endeavored to interest the chambers of commerce and the municipal officers in a similar work in the past.

[5] Consulting Engineer; J. N. Chester Engineers. Pittsburgh, Pa.

[6] President, Water Company, Terre Haute, Ind.

THE HETCH HETCHY WATER SUPPLY OF THE CITY OF SAN FRANCISCO[1]

By M. M. O'Shaughnessy[2]

The Hetch Hetchy Water Supply project of the City of San Francisco is designed to furnish ultimately a daily supply of 400,000,000 gallons or more to the metropolitan district surrounding the bay of San Francisco.

The source of this water is the higher portion of the watershed of the Tuolumne River, in the Sierra Nevada Mountains, where flood-waters will be impounded in reservoirs for transmission by gravity through two mountain ranges and across two broad valleys to a region whose population is expected to pass the 4,000,000 mark within a century (see fig. 1).

As a water supply system, the project is of greater magnitude than any similar development in the United States except the Catskill supply of New York City and the Metropolitan System of Boston. But it surpasses these in being capable of developing also hydroelectric power, to the extent of over 200,000 horsepower.

Though power is a by-product of the water development, the construction work so far undertaken has been limited to that necessary to put in service the first large power generating station. The reasons for this policy will be given later.

PRESENT WATER SUPPLY OF SAN FRANCISCO

The city's earliest supply of water came from wells and springs close to the original settlement near the northerly tip of the peninsula. As the increasing population began to require a greater supply than these sources could produce, additional water was brought in barges from Marin County across the bay, and distributed by water carts.

During the fifties the systematic development of the present water system was begun by two companies. In 1862 these concerns con-

[1] Presented before the Philadelphia Convention, May 16, 1922.

[2] City Engineer, San Francisco, Cal.

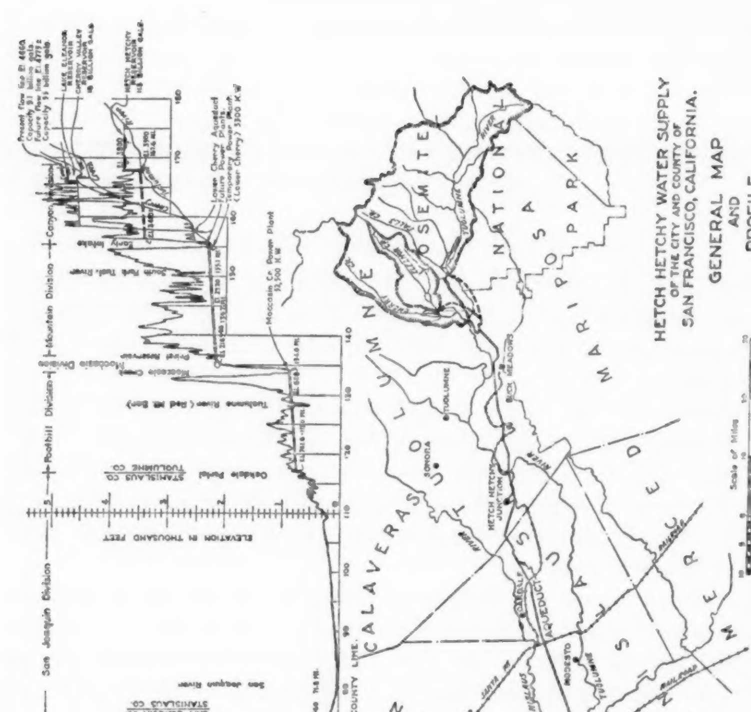

HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.
GENERAL MAP
AND
PROFILE
ELEVATION IN THOUSAND FEET
MILES FROM SAN FRANCISCO - SAN MATEO COUNTY LINE.
Peninsular Division
Bay Crossing Division
Coast Range Division
San Joaquin Division
Foothill Division
Moccasin Division
Mountain Division
Canyon Division
SAN FRANCISCO
SAN PABLO BAY
SAN FRANCISCO BAY
CONTRA COSTA
ALAMEDA
SANTA CLARA
SAN JOAQUIN
CALAVERAS
STANISLAUS
TUOLUMNE
MARIPOSA
MERCED
YOSEMITE NATIONAL PARK
HETCH HETCHY AQUEDUCT

FIG. 1.

solidated under the name of Spring Valley Water Works, which in 1903 was changed to Spring Valley Water Company.

The first real "water works" began in 1858 to deliver water from Lobos Creek within the present city limits. This, as well as some other sources within the city, have long been abandoned.

The next step was southward to the wooded watershed of Pilarcitos Creek in San Mateo County. Here a dam was constructed, and by means of an aqueduct combining one mile of tunnels, 30 miles of flumes and one mile of riveted wrought iron pipes, the delivery of 2,000,000 gallons a day was begun in 1862. Six years later, pipe was substituted for the greater part of the flume line.

By 1888, two additional reservoirs had been developed by building the Crystal Springs and San Andreas dams. This brought the development of the peninsula supply practically to the economic limit.

Alameda Creek, across the bay, had already been adopted as a source of additional water, and has furnished nearly all increments of supply since 1888. The Calaveras dam, which is not yet completed but is already in use, is located on one of the principal tributaries of this creek. Calaveras reservoir is the most distant part of Spring Valley Works, being about 50 miles from San Francisco along the conduit lines.

The average daily supply from the Spring Valley Water Company's sources in 1921 was 36,338,000 gallons.

The three peninsula reservoirs have an aggregate capacity of about 30 billion gallons. The tributary watershed is 35.3 square miles, of which 31.4 square miles is owned by the Company.

The average daily supply to the city from Spring Valley sources is about 36 m.g.d., of which 15 m.g.d. is from the peninsula reservoirs and 21 m.g.d. from Alameda Creek. Completion of the Calaveras development will increase the total dependable supply to 60 m.g.d.

Besides the Spring Valley supply, a large number of wells within the city limits yield about 8 m.g.d., most of which is used for industrial purposes where cheapness is more important than quality.

HISTORY OF THE HETCH HETCHY PROJECT

About fifty years ago the City of San Francisco began to entertain the idea of municipal ownership of its water supply. The first investigations with a view to municipal control were made in 1871.

The principal source of supply at that time was the peninsula watershed of the Spring Valley Water Works.

Several times between 1871 and 1900, municipal ownership of the water supply was agitated, but each time the water company forestalled the city's action. About the beginning of the present century, however, the public began to realize that for the expansion of the supply necessary in order that the city's growth might continue unhampered, it would be essential to develop new sources.

In the year 1900 the city's present charter was adopted. In this charter there is a clause which in effect declares it to be the policy of the city to own its water works. Pursuant to this provision, the Board of Supervisors directed the City Engineer to make an exhaustive study of the subject of additional water supply, taking into consideration all available sources and the future needs of the city.

As the result of the ensuing investigations, the Tuolumne River was selected as the best.

These studies were made in the years 1900, 1901, and 1902. In 1901 the mayor filed notices of appropriation of water on the Tuolumne River, at Hetch Hetchy Valley, and on Eleanor Creek near the site of the present Lake Eleanor Dam.

Hetch Hetchy and Lake Eleanor had been suggested as sources of water supply for San Francisco as early as 1879 by the State Geologist of California, and Hetch Hetchy in 1891 by the United States Geological Survey.

Surveys were begun in 1901 for reservoirs at Hetch Hetchy Valley and Lake Eleanor and for the aqueduct to San Francisco, and on July 28, 1902, the City Engineer filed a report in considerable detail, with maps and plans of proposed structures.

In November, 1901, occurred the first election of the series which resulted in bringing the government of San Francisco into national disrepute. Corporate interests were during all this time looking with much disfavor upon the city's municipal ownership program and the combination of hostile corporations and a number of city officials amenable to suggestions from the corporations, resulted in holding up progress on the project for several years. At last the grafting officials were thrown out of office, and under the new regime the movement for the additional water supply took fresh impetus, and the Board of Supervisors definitely committed itself to the acquisition of the water supply from the Tuolumne River.

As Hetch Hetchy Valley and Lake Eleanor lie within the boundaries of the Yosemite National Park, it was now necessary to enter into negotiations with the government authorities.

On May 11, 1908, Secretary of the Interior Garfield authorized the city to use Hetch Hetchy Valley as a reservoir site in connection with other works on branches of this river, stipulating, however, that the city should develop the Lake Eleanor site to its full capacity before beginning the development of Hetch Hetchy. Thus the city was to be compelled to develop first the smaller and less desirable source, although this arrangement was certain to be much more expensive than if Hetch Hetchy were to be taken first. The bargain was accepted as the best arrangement that could be reached at that time. It was, however, unsatisfactory, being revocable at any time by the Secretary of the Interior.

In the fall of 1908, the voters of the City authorized an issue of $600,000 of bonds for acquiring lands and water rights. Additional work on plans and surveys was entered upon and on January 4, 1910, the people by a 20 to 1 vote, authorized $45,000,000 worth of bonds for construction.

Thus, at the beginning of 1910, the way was paved for the commencement of preliminary construction work. But on February 25 Mr. Garfield's successor as Secretary of the Interior, R. A. Ballinger, called upon the city to show cause why the Hetch Hetchy reservoir site should not be eliminated from the terms of the 1908 permit. This elimination would have limited the possibilities of the Tuolumne project to such an extent that it probably would have become preferable to abandon it entirely and resort to some one of the sources that had been previously rejected as less desirable and more costly.

There now ensued a dispute of nearly four years duration. Working against the city under cover, and inspiring the greater part of the opposition, were powerful financial interests. The open resistance came from the irrigation districts which derive their water supply from the Tuolumne River and from so-called "nature lovers" apprehensive of desecration of the natural beauty of the Yosemite National Park. Much of this latter opposition was due to an erroneous identification of the Yosemite Park, within whose boundaries part of the project lies, and the Yosemite Valley, which lies within the park, but on another river eighteen miles to the south. Many promoters of rival schemes for supplying water to San Francisco aided the opponents of the Hetch Hetchy plan.

The city's vigorous protest against the proposed withdrawal of its rights in Hetch Hetchy brought about the appointment of a board of engineers selected from the Corps of Engineers of the United States Army to study the matter of additional water supply for San Francisco. About the same time, the city engaged Mr. John R. Freeman as consulting engineer to assist in presenting its case.

The work of both Mr. Freeman and the Army Board confirmed the earlier judgment of the City's engineers in pronouncing the Tuolumne the most available source of additional water supply, not only for San Francisco, but for the San Francisco Bay metropolitan region.

The Army Board submitted its report to the Secretary of the Interior February 19, 1913. By this time the municipal officials had reached the conclusion that nothing short of a special act of Congress would make the City independent of the changing moods of successive Interior Department executives. Accordingly, in 1913, the city secured the introduction before Congress of a bill to grant certain well defined permanent rights in the public lands, covering reservoir privileges, rights of way for aqueducts and power lines, etc.

The opposition carried its fight through both houses of Congress, and even beyond, urging the President to veto the bill, which, however, was signed and became effective December 19, 1913.

Terms of the congressional grant

The Hetch Hetchy development is now being carried forward under the authority of the act of Congress of 1913, the principal provisions of which are in substance as follows:

The City and County of San Francisco is granted lands in the Hetch Hetchy Valley, the Lake Eleanor basin, and Cherry Valley, for reservoirs, and lands and rights of way elsewhere in the public lands, for aqueducts, power plants, power transmission lines, roads, railroads, telephone lines, etc.

The City is empowered to enforce sanitary regulations within the water shed tributary to the reservoirs and aqueduct.

The City is required to recognize the prior right of certain irrigation districts of the San Joaquin Valley to receive from the natural flow of the Tuolumne River such water as can be beneficially used by them, up to specified maximum quantities. This entails no obligation to store water for irrigation, but merely reduces the amount that the City may retain in storage or divert for its own purposes out of the quantity entering its reservoirs, when the quantity of water entering the Tuolumne below the City's dams is less than the irrigation priorities.

The City is not permitted to divert beyond the limits of the San Joaquin Valley any more of the waters of the Tuolumne watershed than, together with the waters which it now has or may hereafter acquire, shall be necessary for its beneficial use for domestic and other municipal purposes.

The City is required to develop electric power for municipal and commercial use, up to a minimum of 60,000 horsepower; to construct and maintain certain roads and trails, and to pay to the United States an annual rental graduated up to a maximum amount of $30,000.

Metropolitan water district contemplated

The provisions of the act are extended to "the City and County of San Francisco and such other municipalities or water district or water districts as may, with the consent of the City and County of San Francisco or in accordance with the laws of the State of California, hereafter participate in or succeed to the beneficial rights and privileges granted by this act."

The laws of the State of California provide for the formation of municipal water districts, through the initiative of the legislative body of any municipality and the subsequent ratification, first by the legislative bodies, and then by a majority of the voters, of all municipalities named by the first one in its initial ordinance. The act contemplates the sale of water at wholesale by the district to its component municipalities, the distribution of the water being left to the latter organizations.

No effective steps have as yet been taken toward the formation of such a district embracing San Francisco and the neighboring cities and towns which would be advantageously served by the Hetch Hetchy aqueduct.

Construction period

Preliminary construction was commenced during 1914, and work has been continuous from that time to the present, though difficulties of financing and obtaining workmen and materials, due to war conditions, greatly retarded the progress of the project. It was only in 1921 that the work was at last running "full blast," without interference due to conditions not originating in the project itself.

The course of construction will be indicated in the subsequent descriptions of the various features of the work.

GENERAL POLICY AND CONSTRUCTION PROGRAM

As a matter of sound business policy, the construction program has been arranged with a view to making available at the earliest possible time the works which can earliest be utilized.

The completion of the entire aqueduct will require several years'

TABLE 1

Statistics of Hetch Hetchy and Lake Eleanor Reservoirs

	HETCH HETCHY RESERVOIR		LAKE ELEANOR	
	Initial	Ultimate	Present	Ultimate
Area of watershed, square miles	459	459	79	183*
Capacity of reservoir:				
Millions of gallons	67,000	113,500	9,100	54,900†
Acre feet	206,000	348,500	28,000	168,400
Water surface area, square miles	2.5	3	1.5	2.2
Elevation of roadway on dam, feet	3,726.5	3,812	4,661	4,785
Elevation of spillway crest, feet	3,719.75	3,800	4,660‡	4,775
Length of reservoir, miles	7.5	8	3.1	3.2
Width of reservoir, maximum, miles	0.65	0.7	1.0	1.1
Width of reservoir, average, miles	0.33	0.38	0.5	0.7
Depth of reservoir from spillway crest:				
Maximum, feet	220	300	60†	175†
Average, feet	129	179	29†	119†
Dam:				
Type of dam	Concrete, gravity section arched in plan		Reinforced concrete buttressed arch	Rock fill with concrete facing
Length on crest, feet	600	900	1,260	1,750
Height of crest above stream level, feet	226 (Roadway)	312 (Roadway)	60	185 (Roadway)
Depth from stream level to bedrock at upstream, maximum, feet	101	101	Stream bed is solid rock	
Depth from stream level to lowest point in foundation, feet	118	118		
Height of dam above bedrock at toe, maximum, feet	327	413	61	
Height of dam above lowest point in foundation, feet	344	430	70	
Width at crest, feet	15	25		
Width at base, maximum, feet	298	298		
Volume of masonry, cubic yards	375,000	625,000	11,640	
Type of spillway	Siphon	Channel around end of dam	Overflow	Channel around end of dam

* Includes Cherry watershed above proposed diversion.

† Lake Eleanor depths and capacities do not include that portion of the original lake which is not available for draft.

‡ With flashboards in place: 4,655 without flashboards.

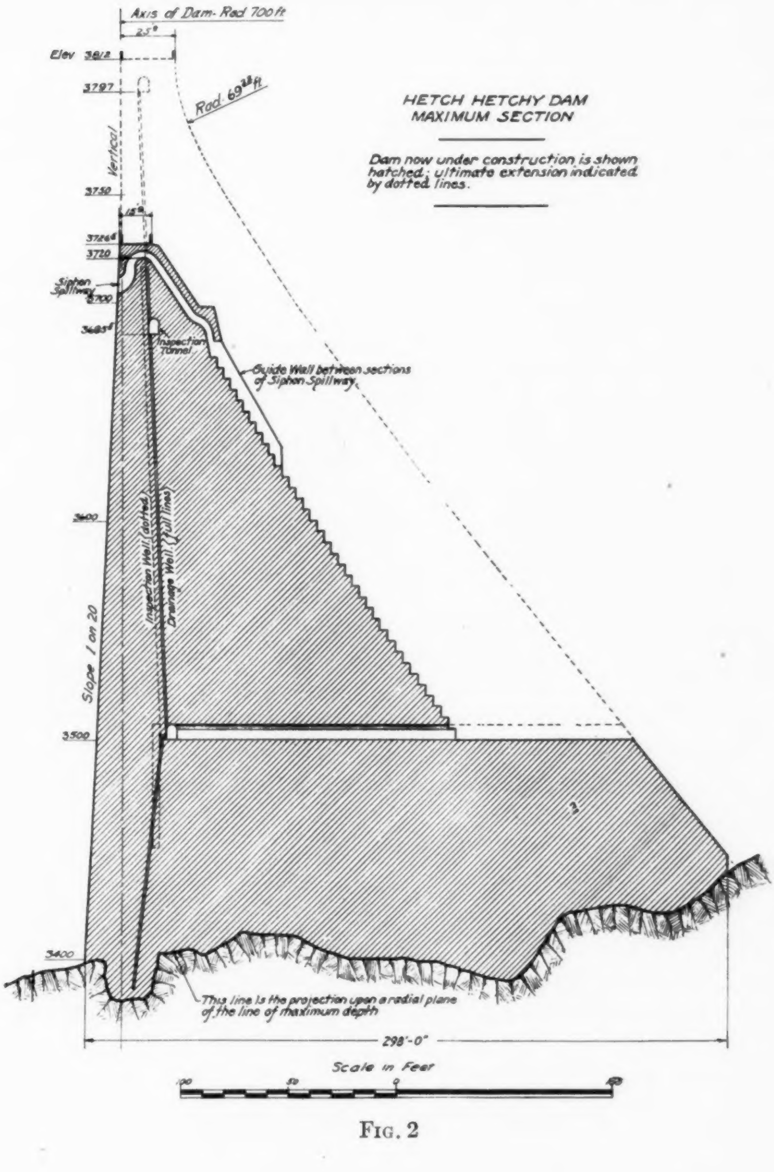

HETCH HETCHY DAM
MAXIMUM SECTION
Dam now under construction is shown hatched; ultimate extension indicated by dotted lines.
Axis of Dam-Rad 700 ft
Elev 3812
3797
Vertical
3750
3720
Siphon Spillway
3700
Inspection Tunnel
Guide Wall between sections of Siphon Spillway
3600
Drainage Well (full lines)
Slope 1 on 20
3500
3400
This line is the projection upon a radial plane of the line of maximum depth
298'-0"
Scale in Feet

Fig. 2

time and a great expenditure of money. The full development of the local supply system of the Spring Valley Water Company will yield sufficient water to take care of the city's needs for ten years or more, so there is no need for haste in bringing in Hetch Hetchy water.

The policy therefore has been to concentrate all resources upon the construction of the portions of the system necessary for the development of the first large hydroelectric power plant, which is now expected to be in operation in about two years. The revenue from power sales will then be applied toward the payment of bond interest and redemption charges, materially lightening the financial burden upon the taxpayers.

The next unit to be undertaken is the construction of the portion of the aqueduct extending from the Spring Valley Water Company's Alameda County sources to San Francisco. The Company's present pipe lines have not sufficient capacity to convey the additional supply which its sources will produce, and rather than permit the company to build an additional conduit, the city will build this link of the Hetch Hetchy system in the near future and rent it to the Company.

The construction of the connecting links across the San Joaquin Valley and the Coast Range Mountains will be deferred until after the completion of the immediately essential parts.

DAMS

There are to be two principal storage reservoirs, Hetch Hetchy and Lake Eleanor, of which some characteristics are given in Table I.

The Hetch Hetchy dam

This dam is located on the Tuolumne River, at the lower end of Hetch Hetchy Valley. It is a concrete dam of the gravity type, and is to be built in two installments (see fig. 2). The first installment, now under construction, will have a height of 226 feet above the original stream bed, and will impound 67 billion gallons of water. The foundation already built, up to the stream bed level, has a maximum depth of 118 ft. below the original stream bed, and is designed to support the ultimate structure, which will stand 312 feet above stream bed and impound 113.5 billion gallons of water.

During the construction of the dam, the Tuolumne River is being diverted from the site through a tunnel, 25 feet wide, 23 feet high and 900 feet long.

The Hetch Hetchy Dam is being built by the Utah Construction Company, under contract, at an estimated total cost of $5,447,792.

Concrete is being placed at an average rate of over 1000 cubic yards daily. The record day's pour so far made is about 1550 cubic yards. The work was contracted for on August 1, 1919, and is expected to be completed in February, 1923.

FIG. 3. HETCH HETCHY DAM SITE—DOWN STREAM FROM ELEANOR ROAD

Outlet system of the Hetch Hetchy dam. The outlet system of the Hetch Hetchy Dam comprises two sets of outlet conduits. One set will be used to discharge water to satisfy the prior claims of irrigators on the lower Tuolumne River. The other set will discharge water to be delivered to the aqueduct.

The valves regulating the quantity of water released into these conduits will be balanced needle valves of the Larner-Johnson type, manufactured by the Cramp Ship and Engine Building Company of Philadelphia.

The balanced valves for irrigation water control will be 6 in number, each 5 feet in diameter. They will be set into the sides of two wells, two at each of three different elevations, and will discharge into 5-foot conduits terminating in the downstream face of the dam. Ahead of each of the balanced valves will be a steel slide gate, hydrauli-

cally operated. The gate valves will not be used to control the flow, but only to shut it off entirely for access to the balanced valves.

FIG. 4. POURING CONCRETE IN HETCH HETCHY DAM, NOVEMBER, 1921. UPSTREAM VIEW

Ahead of the slide gates will be heavy concrete shutters, which can be let down in vertical slots, and which will shut out the water from the gate valves in case the latter require inspection or repair.

To discharge water into the future aqueduct tunnel that will extend from the dam to Early Intake, six three-foot balanced valves will be installed in six conduits, three extending through the body of the dam, at elevation 3625, the other three passing through a concrete plug to be constructed in the existing diversion tunnel, at elevation 3508.

TABLE 2

Power development possibilities

	EXISTING PLANT	PROPOSED PLANTS		
Location of plant	Early Intake	Moccasin Creek	Early Intake	North Mountain
Source of water supply	Cherry River	Hetch Hetchy Reservoir	Hetch Hetchy Reservoir	Lake Eleanor
Aqueduct, type	Flume, canal and tunnel	Pressure tunnel	Pressure tunnel	Canal and tunnel
Aqueduct length, miles (not including pressure pipes)	3.3	19.5	11	7.6
Aqueduct capacity, second feet	200	620	620	200
Forebay, type	Large flume	Reservoir		
Forebay, capacity:				
Gallons	1,500,000	815,000,000		
Acre-feet	4.6	2,500		
Pressure pipes:				
Length, feet	530	4,345	2,500	5,700
Number of pipes	1	4		
Diameter of pipes	3′6″			
Gross drop, feet	345	1,315	1,100	2,000
Power plant:				
24-hour average capacity at power factor 1.00 K. W	3,000	52,500	42,000	24,000
H. P.	4,000	70,000	56,000	32,000
Generators: Number	3	4*		
Capacity each machine, K.W.	1,100	17,500		
Total installed capacity, K.W	3,300	70,000*		
H. P.	4,400	94,000*		

Note:—Development of Huckleberry and Emigrant Lakes as reservoirs will make available additional power, the amount of which has not yet been determined.

* Initial installation. Additional generators to be installed later.

Lake Eleanor dam

Lake Eleanor as a reservoir will be second to Hetch Hetchy, but has already been developed to a capacity of 9 billion gallons, which is about one-sixth of the ultimate proposed capacity. This was done in order to provide water to operate the Lower Cherry power system during the months of low stream flow.

The dam extends across the canyon of Eleanor Creek nearly a mile downstream from the original lake. It is of the buttressed arch type, built of reinforced concrete, and will ultimately be incorporated into a higher structure. It is 1260 feet long, and has a 200-foot spillway. The water is withdrawn through two 24-inch sluice valves on the face of the dam. In addition, there are two 24-inch scouring valves near the bottom of the dam.

Construction of the dam was begun September 1, 1917 and completed late in 1918, entirely by day labor, at a cost of about $290,000.

Fig. 5. Eleanor Dam Under Construction, August, 1918

A diversion dam is to be built on Cherry Creek, about ten miles above its junction with Eleanor Creek. By means of a diversion conduit, about 5 miles long, upper Cherry Creek will be made tributary to Lake Eleanor.

POWER DEVELOPMENT

The entire scheme includes four hydroelectric power plants; one completed, at Early Intake, and three to be built, at Moccasin Creek, Early Intake, and North Mountain. Specific data concerning the four power plants are given in table 2.

A temporary power plant at Early Intake was put into operation in 1918. This plant generates power for the building of the Hetch

Hetchy dam, the tunneling operation, on the 18.3 mile aqueduct now under construction, lighting of the construction camps and the town of Groveland, etc. During the greater part of the year suffi-

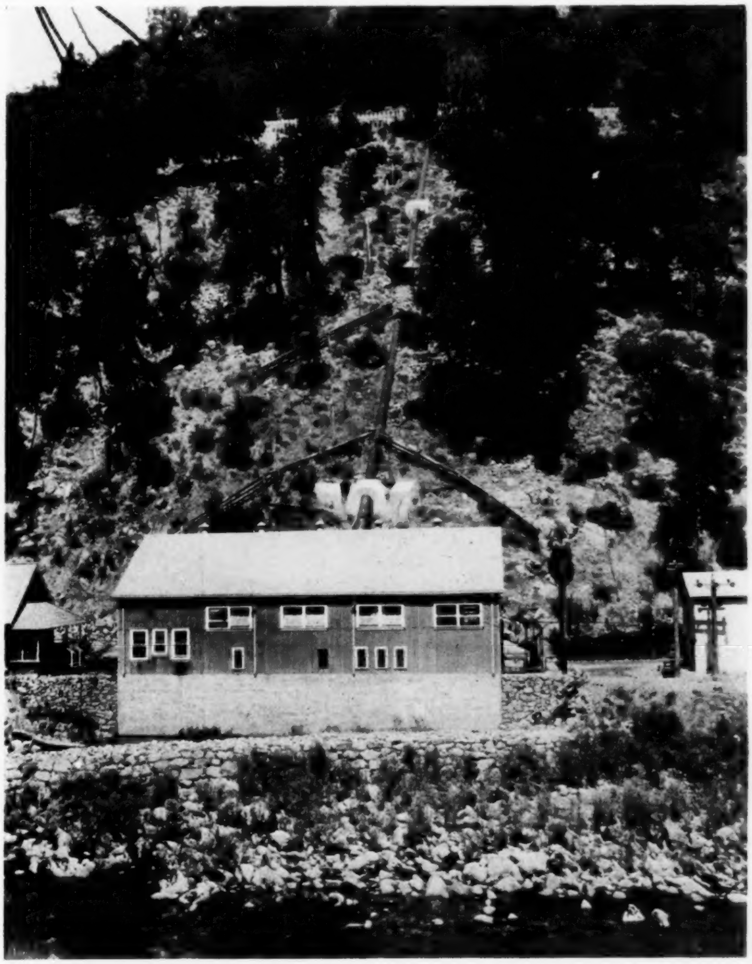


FIG. 5a. TEMPORARY POWER PLANT AT EARLY INTAKE ON THE TUOLUMNE RIVER.

cient water is available to generate more power than the construction work demands. The surplus is then sold to the Pacific Gas and Electric Company, through a connection at Priest.

The water for this plant is supplied from the Cherry River, to which Eleanor Creek is tributary, through a conduit about $3\frac{1}{2}$ miles long, which is to be a permanent feature of the Hetch Hetchy System. After the usefulness of the power plant is over, the conduit will contribute Cherry River water to the main aqueduct, which heads at Early Intake.

TABLE 3

Properties of standard lined and unlined tunnel sections

	LINED	UNLINED
Dimensions:		
Area inside of prescribed line, in square feet	105.63	167.8
Area inside of lining (A), in square feet	87.94	
Area of concrete inside of prescribed line in square feet	17.69	
Excavation inside of prescribed line, in cubic yards per lineal foot	3.912	6.21
Concrete inside of prescribed line, in cubic yards per lineal foot	0.655	
Perimeter, inner side of lining (p) in feet	33.79	
Hydraulic Elements:		
Wetted perimeter (p), in feet	33.79	48.0
Hydraulic radius $\left(r = \frac{A}{p}\right)$, in feet	2.60	3.5
Hydraulic slope (s)	0.00121	0.00118
Coefficient of roughness in Kutter's formula (n)	0.014	0.032
c, in Chezy formula	125.5	57.4
Velocity of water ($v = c\sqrt{rs}$), in feet per second	7.04	3.69
Quantity of water flowing ($Q = A\ v$), in cubic feet per second	619	619

About 20 miles below Early Intake, on the Hetch Hetchy aqueduct line, is the site of the Moccasin Creek Power Plant, which will be the first large unit of power development. It will receive water through the tunnel now under construction from Early Intake, and discharge into a lower section of the aqueduct, to be constructed later.

Topography does not favor the construction of regulating reservoirs above the penstocks of the two other future power plants, and therefore it is planned that in the finished system, they will be operated at constant outputs, and the entire load fluctuation of the system will be absorbed by the Moccasin Creek plant, where an

unusually large forebay reservoir is being provided, as described later.

The Early Intake power plant will be located on the Tuolumne River, 12 miles below the Hetch Hetchy dam. The fall of the water from the reservoir will be conserved by leading it through a tunnel in the canyon wall south of the river from the dam to a point near the power house. Until this unit is completed, the water from the Hetch Hetchy reservoir will flow in the bed of the Tuolumne River to Early Intake.

The North Mountain power plant site is on the Tuolumne River, a short distance above the Early Intake plant. The plant will be supplied with water from Lake Eleanor through a conduit about $8\frac{1}{2}$ miles long, and will discharge into the Tuolumne above the Early Intake diversion, thus making Lake Eleanor tributary to the main aqueduct.

THE AQUEDUCT

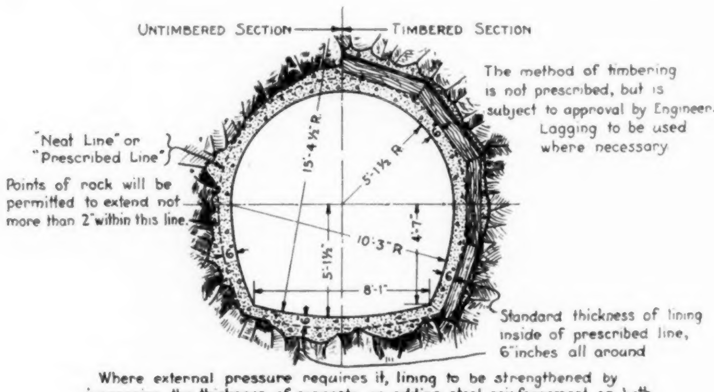
The Mountain Division of the aqueduct begins at Early Intake, where the water, first from Hetch Hetchy, and later also from Lake Eleanor, will be turned by a diversion dam from the river into a tunnel, 18.3 miles long. Standard lined and unlined sections of the tunnel are shown in figures 6 and 7, and their dimensions and hydraulic properties listed in table 3. The unlined section is used for about six miles of the total length, in which distance the rock encountered is very hard and sound. Fifty-nine per cent of the tunnel excavation is now completed. (March, 1922).

At the lower end of this division is the Priest Reservoir, which is the forebay for the Moccasin Creek power house. The reservoir will be formed by building an earth and rock fill dam, 145 feet high, containing about 800,000 cubic yards, with a concrete core wall, across a small gulch. The capacity of the reservoir will be 800,000,000 gallons, or two days flow of the aqueduct at its maximum capacity. The dam is now under construction. The major part of the earth fill is to be placed by hydraulic sluicing.

After being discharged from the Moccasin Creek power house, the water will enter a tunnel similar to the one above, and continue underground for 17 miles, to Oakdale Portal.

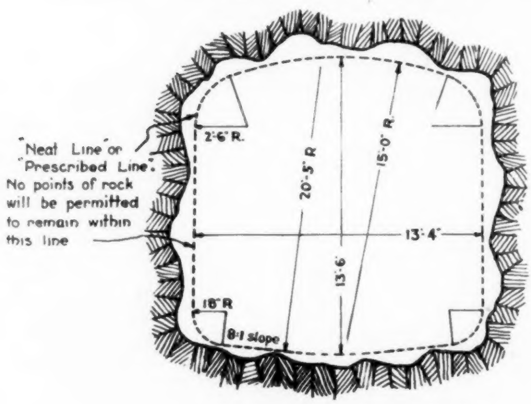
Pressure tunnels

The Hetch Hetchy aqueduct is unique in its use of long tunnels operating under pressure. The tunnels are placed 20 to 70 feet below the hydraulic grade line and will flow full. The slope of the



Standard Lined Tunnel Section

Figure 6



Standard Unlined Tunnel Section

Figure 7

hydraulic grade line is less than that of the tunnel itself, the two rates being, in the tunnel from Early Intake to Priest reservoir, 0.0012 and 0.00155, respectively. As the flow capacity of an aqueduct can not be predicted with a great degree of certainty, prudence requires the designer to anticipate the worst conditions, where the

aqueduct is to be constructed at once of its full ultimate size. Thus there is always a probability that the actual conditions will be better than those assumed in design. When the aqueduct is operated under pressure, if the actual loss of head in any section is less than that assumed, the difference may be advantageously used in other sections of the development. This would not be possible with conduits located at hydraulic grade. In the Early Intake—Priest tunnel, each foot of head so conserved will operate to increase the power output of the Moccasin Creek plant by about 55 horsepower.

San Joaquin Valley crossing

The San Joaquin Valley will be crossed by steel pressure pipes, extending 45 miles from Oakdale portal to Tesla portal. To develop the ultimate capacity of 400 million gallons per day, three pipes of about seven feet diameter will be required. The detailed plans for this section and for the Coast Range tunnel have not been definitely fixed, and the program of construction will be partly determined by the action of the municipalities around San Francisco Bay in the matter of forming a water district.

The Coast Range will be penetrated by pressure tunnels, 31.5 miles from Tesla Portal to Irvington Gate House, broken by a steel siphon crossing the canyon of Alameda Creek. The hydraulic grade rate of this tunnel will be less than the slope from Moccasin Creek to Oakdale Portal, the tunnel cross-section being made larger than in the Sierra Nevada.

Distribution

At Irvington Gate House, ten miles east of the Bay, water for destinations other than the San Francisco peninsula will be diverted from the main aqueduct into branch conduits not yet planned. The pipes and tunnels connecting Irvington Gate House and San Francisco are being designed for an ultimate capacity of 200,000,000 gallons daily.

From Irvington Gate House across San Francisco Bay and the adjacent low lands to Redwood Portal will be about 20 miles of pipe. The line crosses the bay at Dumbarton Strait, whose width is 1.3 miles, and maximum depth 50 feet. The ultimate development here will require three pipes, each over six feet in diameter. A 5-foot pipe will be used for the initial stage.

From Redwood Portal to San Francisco the aqueduct will consist of alternating sections of tunnel and pipe, totaling about 20 miles. In order that a large supply of water may always be available in storage near San Francisco, connection is to be made from the tunnel to the Crystal Springs Reservoir of the Spring Valley Water Company near Redwood Portal.

Within the city limits will be the Amazon Receiving Reservoir, the terminus of the aqueduct. Its capacity will be 300 million gallons, and its high water elevation 248 feet above sea level. About half the total city supply will be distributed from this reservoir by gravity.

The aqueduct from the east side of the bay to Crystal Springs Reservoir is the section which, as before noted, is to be constructed in the immediate future to make available the additional water supply from local sources. It will receive water from the Spring Valley Water Company's conduit near Irvington. The existing pipe lines between Crystal Springs Reservoir and San Francisco are capable of carrying more water than they now receive, permitting deferring construction of the parallel Hetch Hetchy aqueduct.

AUXILIARY WORKS

Besides the temporary power plant already mentioned the City carries on several other auxiliary enterprises developed preliminary to the construction work.

Hetch Hetchy Railroad

Most important of these is the Hetch Hetchy Railroad, which was built during the period 1915–1918, to transport construction materials to the Hetch Hetchy Dam and the easterly divisions of the aqueduct. It is a standard gage railway, 68 miles long, extending from the dam to Hetch Hetchy Junction, at which point it connects with the Sierra Railway of California. The latter connects with the Southern Pacific and the Santa Fe railroads at Oakdale, 26 miles from Hetch Hetchy Junction.

From Hetch Hetchy Junction, the railroad extends easterly to the Tuolumne River. It follows the river to Moccasin Creek, and from there follows a ridge route, ascending from an elevation of 700 feet at Moccasin Creek, to a summit at elevation 5064, and descending again to elevation 3870 at its terminus near Hetch Hetchy

Dam. The road is operated as a common carrier. Besides its principal function of transporting materials for the dams and aqueducts, it carries passengers and hauls some lumber and general freight for parties not connected with the project.

Sawmill

The city operates a sawmill at Mather, nine miles below Hetch Hetchy on the Tuolumne River. The mill was first constructed in 1915, but was moved in 1920 to its present location. Yellow

FIG. 8. PORTAL OF HETCH HETCHY AQUEDUCT TUNNEL, SHOWING MYERS-WHALEY MUCKING MACHINE USED TO REMOVE DEBRIS, AUGUST, 1921

pine, sugar pine, red fir and cedar are cut within a radius of about a mile from the sawmill, and hauled to the mill with donkey engines and cables. The capacity of the mill is 25,000 to 30,000 feet per 8-hour shift. Over 10 million feet of lumber have been sawed since the mill was established at Mather. All lumber used on the project was produced at this mill, except the redwood and Oregon pine used on the railroad, and the lumber used in building the Lake Eleanor dam. The latter was cut and sawed at Lake Eleanor.

Shops

The city's machine and blacksmith shops and car repair shop at Groveland do practically all the repair work and overhauling of the rolling stock of the Hetch Hetchy Railroad, and also such work on the construction machinery as cannot be handled by the small shops at the various camps.

FIG. 9. CITY SAWMILL AND POND AT MATHER

Medical service

At Groveland the City maintains a hospital, with a physician and 3 nurses. Both industrial and non-industrial casualties are handled by the City's medical service. For service in illness and accident cases not resulting from their employment, the employees are charged $1.00 per month each. For providing service in industrial accident cases, against which it carries insurance with the California State Compensation Insurance Fund, the City is allowed a 15 per cent rebate on the premiums.

ORGANIZATION AND MANAGEMENT

The Hetch Hetchy development is one of the activities of the Department of Public Works of the City and County of San Francisco. The City Engineer is Chief Engineer of the project, and the Chief Assistant Engineer has direct charge of the work.

Two Construction Engineers, located at Groveland and Hetch Hetchy, report to the chief assistant engineer.

Headquarters engineering work is carried on at the City Engineer's office in San Francisco. Field headquarters for the work now in progress are at Groveland, 27 miles by rail from Hetch Hetchy Junction.

The number of employees in the field reached a maximum of 1643 in November, 1921. In February, 1922, the number was 1423, which will be exceeded when the weather conditions permit more rapid work on the various construction units. Total expenditure up to the end of the year 1921 were about $16,500,000. Net expenditures for the fiscal year of 1920–21 were about $3,474,000.

Personnel

The engineering staff of the project includes:

General:
M. M. O'Shaughnessy, City Engineer of San Francisco, Chief Engineer;
N. A. Eckart, Chief Assistant Engineer.

City Office Staff:
Leslie W. Stocker, Assistant Engineer
R. P. McIntosh, Hydraulic Engineer
R. J. Wood, Structural Engineer
Paul J. Ost, Electrical Engineer
Edwards P. Jones, Mechanical Engineer

Construction:
C. R. Rankin, Construction Engineer, Hetch Hetchy Dam.
Lloyd T. McAfee, Construction Engineer, aqueduct tunnels and Superintendent, Hetch Hetchy Railroad.

The following are among the experts who have acted as consultants on the project.

Mr. John R. Freeman, Civil Engineer.
Mr. Frank G. Baum, Electrical Engineer
Dr. Wm. F. Durand, Mechanical Engineer
Dr. James C. Branner, Geologist
Mr. John D. Galloway, Civil Engineer.
Prof. Charles D. Marx, Civil Engineer.

MODERN PRACTICE IN THE REMOVAL OF TASTE AND ODOR[1]

By Norman J. Howard[2]

Of recent years, in the sanitary world, the question of taste and odor in public water supplies has received universal attention. The prevention of taste is of considerable importance, and each year sees further advances made not only in the study of removal, but of taste prevention. It would seem that the solution to such problems would largely depend upon active laboratory work. Practical observation, chemical experiment and microscopical examination should, and frequently actually do indicate causes. With these established, and seasonal or periodic incidence recorded, prevention should be possible. The margin between taste and odor is small and often complaints of taste are made when only slight odors exist. Where complaints are justified, publicity as to the real cause of taste will often do much to satisfy consumers, who usually are more concerned with the safety of the supply than with objectionable taste. The description of taste and odor presents difficulties, on account of their extensive nature. The purpose of this paper is to deal with the commoner conditions found in practice and to discuss briefly methods of elimination and prevention. At the outset it should be stated that laboratory research has frequently demonstrated that certain tastes cannot be removed immediately, but, that once their cause has been established, elimination speedily follows.

At the present time, problems involving taste are largely confined to excessive algae growths and to the formation of chemical compounds following the sterilization of water with chlorine. The presence of iron and gases may also give rise to complaints. The discharge of various industrial wastes into rivers and streams, from which water supplies are drawn, is the cause of many difficult problems that engineers and sanitarians must solve. It is proposed to deal in this paper with taste and odor removal by aeration, filtration

[1] Presented before the Philadelphia Convention, May 19, 1922.

[2] Bacteriologist in Charge, Filtration Laboratories, Toronto, Canada.

and chemical processes. Time does not permit elaboration on the methods of aeration and filtration in general practice, since it is assumed that aeration means the rapid exposure of water to air with a subsequent oxidation of the organic matter and the removal of excessive carbonic acid and certain odor producing gases. In general, where filtration is employed, aeration should follow the filtration process. Where odors result from gas production, or when iron in solution is present, aeration prior to filtration is preferable.

Water containing iron in excess of two parts per million will give a taste described as inky, while water containing iron and sulphuretted hydrogen give a particularly offensive odor, although the gas may be readily removed by aeration. The cause of sulphuretted hydrogen in water, particularly in well supplies, may usually be demonstrated by a topographical survey. Such waters may be exceptionally pure, and, if the gas formation is not produced by the reduction of sulphates, then some inorganic reducing agent may be the cause. In waters containing calcic sulphate and organic matter, a calcic sulphide is formed, even at ordinary temperatures, by the action of the organic matter on the sulphate. The sulphide is decomposed by the carbonic acid and sulphuretted hydrogen is liberated, which imparts to the water an unpleasant taste. Waters containing iron and gases invariably contain carbonic acid in large quantities. When iron is in solution, as a ferrous carbonate or sulphate, aeration produces precipitation, the iron coming down in an oxidized state. If iron is present in large quantities, it may be necessary to aerate the water or introduce air under pressure, and subsequently to apply lime or alum. The resultant precipitate would have to be settled out before filtration. Calcium hypochlorite has been successfully used in the removal of odors and iron, and has been shown to possess remarkable powers of oxidizing organic compounds. The whole question of nuisance arising from the presence of gases and iron in solution may usually be solved by aeration and filtration processes.

TASTE FROM MICROSCOPIC-ORGANISMS

Taste and odor from the presence or decomposition of microscopic organisms are world-wide. Seasonal variation in the developments of algae is more or less controlled by climatic conditions. For the purposes of this paper the subject may be divided into two group-

ings, bacteria and algae. The direct relation of bacteria to taste, with the exception of crenothrix, is not apparent. Bacterial decomposition causing taste and odor has followed the discharge of sewage and other wastes into rivers and streams deficient in oxygen. The effluents from creameries are particularly offensive, forming fungoid growths which rapidly decompose and produce foul conditions. In slow flowing streams the discharge of putrescible matter is objectionable and may cause highly offensive tastes and odors. As these invariably occur during warm weather and frequently are only of short duration, the installation of aeration plants is hardly justified, and filtration alone will do much to remove the objection. Chlorine treatment will also materially assist, by preventing the putrefying conditions. Ordinarily, taste does not result from crenothrix, but this organism in the presence of iron, with which it is always associated, may produce a characteristic taste. There are cases on record where decomposition of crenothrix has imparted a distinct taste. Here again, aeration followed by filtration is effective. Filtration alone has proved beneficial not only in removing the organisms, but in reducing the iron content. Laboratory experiments, conducted at Superior, Wis., some few years ago, where the water prior to treatments was highly colored, and contained crenothrix in large numbers, demonstrated the fact that crenothrix was completely removed by the filters without aeration, but that heavy deposits on the surface of the filters caused considerable trouble by shortening the filter runs.

Complaints of taste and odor arising from excessive algae growths are frequently encountered. They are, however, somewhat easier to overcome on account of the definite cause being known. Their removal requires much skill and careful supervision. Treatment of such waters usually involves a pre-chemical application of copper sulphate or other reagents, followed by aeration or filtration. The writer feels that water conditions vary enormously and the amount of chemical found sufficient in one case may prove totally inadequate in another. In other words, the application should be based not only upon the microscopic content, but upon the physical and chemical nature of the water. The definite establishment of free and half-bound carbonic acid and of the organic matter present is of great importance, decomposition and solubility of copper sulphate being dependent upon these conditions. The number of algae causing trouble is so great and well known, that it is needless to

dwell upon this subject. It is assumed that taste and odor do and will develop in all cases, when specific organisms are present in sufficient numbers. During the past few years, great advances have been made in the elimination of complaints arising from excessive algae growths. The brilliant research work of Sir A. C. Houston on the London water supply has suggested radical changes of importance. He was able to demonstrate in England that "in certain cases objectionable taste in waters resulting from algae growths could be removed by the addition of minute doses of permanganate of potassium. The dose varies with the oxidisability of the particular water involved, but in dealing with the London supply, the innocuous dose of about 2.5 to 5 pounds of permanganate per million gallons of water was found to destroy the taste in a few minutes. The faint preliminary pink tinge imparted by the addition of the permanganate rapidly faded away, and, in practice, the consumer received a tasteless water with no pink tint, but slightly browner in color than normal."

He points out that such treatment is only admissable in special circumstances. Houston's further researches demonstrate that excess chlorine or permanganate was able to remove certain tastes which frequently followed the application of chlorine for sterilization purposes. When working on the New York supply recently Brush and Hale were able to show that copper sulphate was successful in killing large numbers of organisms including tabellaria, asterionella and synura. Chlorine was applied and caused a reduction in the number of organisms, though not to the same extent as copper sulphate. The most interesting feature of their work was the fact that, in one case where tabellaria was found, it was shown that the numbers present were insufficient to cause taste, yet, after chlorine was applied, objectionable taste followed. In the taste resulting from synura, the application of chlorine was increased from 0.3 up to 0.73 part per million. A sample taken 1500 feet down the stream from the point of chlorine application and tested fifteen minutes after addition, showed the synura taste to be reduced and a combination of synura and chlorine taste to be present. Samples collected about eight hours later, showed a slight chlorine taste, but the cucumber taste from the synura had disappeared. Brush states "Whether the excess chlorine oxidizes the synura oil, or forms a tasteless compound is not known, but whatever may be the chemical reaction, the important factor for water-works operators is the

removal of taste." Later he adds: "The increase in copper sulphate apparently more promptly and completely destroys the organisms, and thus fully exposes its oils to mechanical removal in the flow through the aqueducts and to the later chemical reaction with the chlorine at Kensico. The increase in the chlorine does destroy to some extent the organisms, but its more important action appears to be a rapid neutralization of the synura oil through a chemical process." The work of Brush and Hale has demonstrated on a large scale the practicability of removing taste and odor by treatment with copper sulphate and excess chlorine. Their findings may be of great value in solving future problems of a similar nature.

Some interesting observations were made by Hannan in the laboratories at Toronto, to determine if algae were sensitive to differences in alkalinity, as well as to hydrogen-ion concentration. It was noted that in a water containing a luxuriant growth of algae (chlorophyceae) which was treated with normal acids: (1) enough to nearly neutralize the alkalinity, (2) equivalent to about one-third the alkalinity, marked changes occurred. In the nearly neutralized water in warm weather, growths stopped in less than three days, and died off, whilst in the partly neutralized sample the organism thrived. Possibly the alkalinity acts as a carrier of carbonic acid between the atmosphere, etc., and the algae. When the algae are flourishing, the hydroxyl-ions will generally be found to be high, and, as it is lowered, a point occurs where they may die off rapidly. It should be mentioned that Houston found that, in waters containing fragellaria and asterionella the addition of acid produced no ill effects upon the organisms. He states: "In some experiments the dissolved carbonic acid in the water was first neutralized, in others it was increased by the addition of traces of acid, but in neither case was any constant or appreciable difference in results observed from those just described." The explanation of these two conditions is somewhat problematical, and it may be that there is a definite range for the development of each type of organism. It is well known that different quantities of copper sulphate are required to treat different organisms and it is possible that different hydrogen-ion concentrations may also play an important part in the development and death points of these lower forms of vegetable life. This is a matter which should be demonstrated on a practical scale where opportunity occurs. If it were found that hydrogen-ion concentration controls the situation, the treatment would be simple.

TASTE AND ODOR FOLLOWING CHLORINATION OF WATER

The greatest objection raised against the chlorination of water has been the production of taste and odor in certain supplies. This condition has at times been used as an argument against the installation of sterilizing plants, and it must be admitted that, where these objectionable conditions periodically occur, they constitute a real nuisance. In many cases taste could be overcome if authorities would make a thorough investigation definitely to establish a cause. The City of Toronto has just authorized a year's research work on this important subject, and the preliminary observations carried out are most encouraging. The cause of taste following the chlorination of water is not definitely established. Yet the removal of the cause of certain controlling conditions, observed at Milwaukee and elsewhere, has resulted in the elimination of taste. In treated waters two types of taste occur, a chlorine and a medicinal taste. The latter is sometimes described as resembling iodoform. Each taste generally occurs separately. The writer has no record where chlorine and iodoform taste have been reported present at the same time. Often excess chlorine smells and does not taste, but the iodoform compound both tastes and smells, particularly when the water temperature is above 50°F. The cause of the chlorinous taste is, as the word implies, due to excess chlorine, while the cause of the iodoform taste is said to be due to the presence of chloro-phenols. Extensive observations made by the writer have not convinced him that this is the sole cause, although it must be admitted that phenol in small quantities does combine apparently with chlorine to form chemical compounds which produce offensive tastes and odors. Laboratory work carried out during the past few months has produced some surprising and at times puzzling results. It has been assumed generally that the presence of organic matter was essential for the production of iodoform taste in chlorinated water. In distilled water treated with taste-producing doses of chlorine and phenol, the characteristic iodoform taste is not produced, but a pronounced chlorinous taste results. If this same water is passed through a rapid sand filter, the organic matter or some unknown substance taken up by the water produces most offensive taste and odor. Inversely, slow sand filtered water after treatment with chlorine and phenol develops a taste which is greatly lessened, however, by its passage through the same filter. When in Europe last summer,

records were shown to the writer indicating that the presence of organic matter and phenol was not necessary for the production of the iodoform taste. A deep well water of great purity and free from phenols had received some slight surface water pollution and consequently was chlorinated. The well formed part of a supply for a large community and, after treatment with a small dose of chlorine, a pronounced iodoform taste resulted. One is forced, therefore, to the opinion that, while organic matter and phenols contribute to taste production, in certain cases there must be other causes which act in a similar taste-producing manner. In support of this, it should be pointed out that, at Toronto, where industrial wastes are discharged into the city sewers all the year round, and extensive tests are daily made on the raw water, the iodoform taste occurs largely in the early spring and late fall. If phenol were the only cause of this taste, objectional conditions would prevail throughout the year. The obvious answer is that, at certain low temperature periods, some other organic or vegetable matter combines with chlorine or phenol or both and these compounds produce the conditions complained of. It is also possible that, if phenol is the direct cause, increased biological activity in the warm summer months assists in preventing the formation of obnoxious chemical compounds. Before discussing the iodoform taste in detail, it would be well to dwell briefly upon the chlorinous taste or odor, which not infrequently occurs under two conditions: first, in water comparatively free from pollution, and, second, in water where too great a quantity of chlorine has been applied. The elimination of the first named condition is practically impossible, except by aeration which is neither practical nor necessary. Water containing a small excess of chlorine, particularly when the temperature is low, has a slight odor when first drawn from the tap, but this rapidly disappears upon exposure to the air. In waters containing chlorine in excess of the amount necessary for sterilization purposes, both taste and odor exist. Tea made from such water will have a most objectionable taste due to the action of the chlorine on the extractive matter present. As is the case when phenol is present, it is possible that some similar compound is formed by the combination of chlorine and tannin. The chlorine absorption method, as suggested by Wolman and Enslow, is very practical. As several observers have reported the elimination of taste since using this system, it would seem well worthy of adoption. In Toronto, the establishment

of color standards was found to reduce greatly the chlorinous taste. The dosage necessary for sterilization purposes was worked out, and the blue color produced by definite doses of chlorine, in the presence of starch and iodide, was matched artificially. By making up color standards numbered 1 to 5, and establishing the fact that colors 3 to 5 were sufficient to sterilize the water under varying conditions, chlorine operators were instructed to keep their dosage within these color ranges. This is not put forward as a solution for taste elimination. Since its adoption in Toronto, however, the number of complaints has been greatly lessened. The colors do not represent any definite quantity of applied chlorine, but generally speaking colors 3 to 5 represent approximately an application of 0.175 to 0.225 parts per million of chlorine with a water temperature ranging between 33° and 45°F. As the water warms chlorine is absorbed more rapidly and with a temperature of 68°F., it may be necessary to apply 0.375 parts of chlorine to maintain a color of 3 to 4. The organic content and temperature of the water will be found to control practically the rate of chlorine absorption. The formula for preparing the color standards is as follows.

STANDARD NUMBER	DISTILLED WATER	0.01 PER CENT BRILLIANT MILL GREEN. S.	0.01 PER CENT CARDINAL RED. J.
	cc.	*cc.*	*cc.*
1	150	4	0.866
2	150	5	1.053
3	150	6	1.10
4	150	7	1.15
5	150	8	1.25

The standards should be made up weekly, placed in China cups and protected from the light. In all taste producing conditions there must be controlling factors and often it is difficult to avoid taste without taking chances on the final quality of treated water, particularly where it is unfiltered.

By far the most serious taste to overcome is the iodoform one, because, when the taste has once developed, its elimination is difficult. In general, water which tastes after treatment with chlorine improves on storage, but, when the iodoform taste is present, it steadily deteriorates, and should it warm up, a chemical odor can be detected. In connection with the production of this taste, Houston's remarks

as recorded in his Fifteenth Annual Report are of considerable interest. He states:

His experience has indicated that the iodoform taste can practically always be removed or prevented, either by increasing the dose of chlorine sufficiently, or by adding potassium permanganates as well as chlorine to the water. In the former event, the excess of chlorine may have to be removed by dechlorination (solution of sulphurous acid gas, sodium sulphite, bisulphite, or thiosulphate) and in the latter case it is desirable to remove the precipitate of manganese oxide. The permanganate can be used before, at the same time as, or after the addition of chlorine, that is, it can be used either to prevent the occurrence of the iodoform taste, or to remove it after it has already developed. Similarly, the whole of the super-dose of chlorine may be added to the water at one time, or more chlorine may be added to overcome an iodoform taste, which has already occurred in a chlorinated water. Enormous doses of chlorine (one in 11,000) may be added to water and the taste of chlorine entirely removed by the use of a suitable anti-chlor (de-chlorination). When, however, the chlorinated water has developed the iodoform taste, de-chlorination is powerless to remove it.

One of the most important observations made was that, when dealing with filtered water, chlorine or permanganate could be used before, or after filtration, or chlorine added before and the permanganate after filtration, but the addition of permanganate before and chlorine after invariably produced an iodoform taste. The experiments as conducted by Houston usually involved several hours contact. In this country, this condition is difficult to attain since the water often passes into use almost immediately after treatment. This, of course, does not apply to cities where the supply comes from impounding reservoirs or where the works are located outside the city limits. The cause of the iodoform taste has been the subject of extensive research. The officials of the City of Milwaukee are credited with being the first to demonstrate the relationship of phenols and chlorine to the production of taste. During the past few years in Toronto, extensive investigations have been made upon taste-producing conditions. Numerous hypotheses have been advanced from time to time and have included the microscopic content, the biological content, the formation of chloramines and latterly the formation of chloro-phenolic compounds. The relation between microscopic and biological content and iodoform taste has not been demonstrated, although, when taste does develop, there is often a pronounced increase in both conditions in the raw water. Similarly, abnormally high free ammonia has periodically

occurred at these times and the formation of chloramines has been suggested. This latter compound of ammonia and chlorine actually produces an objectionable taste and smell when occurring under pollution conditions. Curiously enough, when chloramine is used as a sterilizing reagent, no taste occurs.

Daily tests have recently been made in Toronto to determine the phenolic content of the raw and filtered water. Results have shown that when the water was polluted with sewage containing industrial wastes, phenol was present in quantities up to 0.012 p.p.m., the average figure in March and April being 0.00173 and 0.0021 p.p.m. in two intakes respectively. The first named figure was reduced by slow sand filtration to 0.00083 part and the latter figure to 0.0011 by the drifting sand plant, an approximate reduction of 50 per cent. The slow sand system gives a slightly higher removal. Iodoform taste occurred in the city water with a residual phenol content of 0.006 p.p.m. when only 0.2 part of chlorine was applied. This actual condition confirmed the laboratory experiments described later in this paper. Generally speaking, laboratory tests, when using a small rapid sand filter, have shown a remarkable decrease in taste with and without the application of aluminum sulphate.

Owing to the uncertainty as to the controlling factors in iodoform taste, one is compelled to deal with established conditions, which at present time are limited to phenol. The estimation of phenol when present in small quantities is difficult, methods at present in use giving unreliable results. The system as devised by Trowbridge at Newcastle, Pa., would appear to be the best in use, but the writer has not always been able to completely recover amounts of applied phenol when using his method, or to secure satisfactory blanks. When working in the Toronto laboratories, using Lake Ontario water, we have been able to establish the definite dosage of chlorine and phenol which combines and forms the iodoform taste. The chief point established is that the critical figure which causes taste is close to the actual dose of chlorine applied in many cities, thus explaining why taste so often occurs. The following table gives the quantities of phenols and chlorine applied, and the taste and odor condition which resulted.

The tables presented above are longer than originally intended, but it is felt that their publication will indicate better the taste range and possibly be of assistance in finding a solution to the problem in general. It should be clearly understood that these results

Taste conditions when using Lake Ontario slow sand filtered water with varying doses of chlorine and phenol

					0.017 p.p.m. of phenol							
Cl, p.p.m.	0.091	0.182	0.273	0.364	0.455	0.546	0.637	0.728	0.819	0.910	1.37	1.82
Taste—45 min.	tr. I	s. I	I	tr. I	I	Cl	Cl	Cl	s. Cl	s. Cl	s. Cl	s. Cl
18 hrs.	tr. I	s. I	s. I	tr. I	I	tr. Cl	tr. Cl	tr. Cl	s. Cl	s. Cl	s. Cl	s. Cl
Odor—45 min.	tr. I	s. I	s. I	?	Cl	Cl	Cl	Cl	s. Cl	s. Cl	s. Cl	s. Cl
18 hrs.												
					0.015 p.p.m. of phenol							
Cl, p.p.m.	0.090	0.135	0.181	0.226	0.271	0.316	0.362	0.452	0.543	0.633	0.724	0.905
Taste—45 min.	none	tr. I	s. I	s. I	I	I	s. I	s. I	none	?	?	Cl
18 hrs.	none	tr. I	I	I	I	I	I	tr. I	none	tr. Cl	Cl	s. Cl
Odor—45 min.	none	none	I	?	I	I	I	I	none	tr. Cl	Cl	s. Cl
18 hrs.	none	tr. I	I	I	s. I	I	I	none	none	tr. Cl	Cl	s. Cl
					0.013 p.p.m. phenol							
Cl, p.p.m.	0.089	0.133	0.177	0.221	0.266	0.310	0.354	0.443	0.531	0.619	0.708	0.886
Taste—45 min.	none	tr. I	tr. I	I	s. I	s. I	s. I	I	tr. Cl	Cl	Cl	s. Cl
18 hrs.	none	none	tr. I	I	I	tr. I	tr. I	?	none	none	Cl	s. Cl
Odor—45 min.	none	none	tr. I	tr. I	I	I	tr. I	tr. I	Cl	Cl	Cl	s. Cl
18 hrs.	none	none	none	I	I	tr. I	none	none	none	none	?	Cl
					0.010 p.p.m. of phenol							
Cl, p.p.m.	0.078	0.118	0.157	0.196	0.235	0.274	0.313	0.392	0.470	0.548	0.626	0.783
Taste—45 min.	none	?	tr. I	tr. I	tr. I	none	none	tr. Cl	tr. Cl	tr. Cl	tr. Cl	Cl
18 hrs.	none	?	tr. I	I	s. I	s. I	tr. I	none	none	none	?	?
Odor—45 min.	none	none	none	tr. I	tr. I	none	none	tr. Cl	Cl	Cl	Cl	s. Cl
18 hrs.	none	none	none	I	I	tr. I	none	none	none	none	?	Cl

0.009 p.p.m. of phenol

Cl, p.p.m.	0.104	0.156	0.208	0.260	0.312	0.364	0.416	0.520	0.624	0.728	0.832	1.04
Taste—45 min.	none	none	tr. I	I	s. I	I	?	Cl	Cl	Cl	Cl	Cl
18 hrs.	none	?	?	tr. I	s. I	tr. I	none	none	tr. Cl	Cl	Cl	Cl
Odor —45 min.	none	none	none	none	I	I	Cl	Cl	Cl	Cl	Cl	Cl
18 hrs.	none	none	none	tr. I	I	tr. I	none	none	tr. Cl	Cl	Cl	Cl

0.007 p.p.m. of phenol

Cl, p.p.m.	0.104	0.156	0.208	0.260	0.312	0.364	0.416	0.520	0.624	0.728	0.832	1.04
Taste—45 min.	none	?	tr. I	tr. I	s. I	?	?	?	Cl	Cl	s. Cl	s. Cl
18 hrs.	none	none	tr. I	tr. I	tr. I	?	none	none	s. Cl	s. Cl	s. Cl	s. Cl
Odor —45 min.	none	?	?	?	L	tr. I	tr. Cl	tr. Cl	Cl	Cl	s. Cl	s. Cl
18 hrs.	none	none	tr. I	tr. I	I	?	none	none	s. Cl	s. Cl	s. Cl	s. Cl

0.005 p.p.m. of phenol

Cl, p.p.m.	0.092	0.138	0.184	0.230	0.276	0.322	0.368	0.460	0.552	0.664	0.737	0.920
Taste—45 min.	none	none	tr. I	tr. I	s. I	Cl	Cl	Cl	Cl	s. Cl	s. Cl	s. Cl
18 hrs.	none	none	?	?	I	tr. I	?	Cl	Cl	Cl	s. Cl	s. Cl
Odor —45 min.	none	none	?	tr. I	I	Cl	Cl	Cl	Cl	Cl	s. Cl	s. Cl
18 hrs.	none	none	none	none	tr. I	tr. I	?	Cl	s. Cl	s. Cl	s. Cl	s. Cl

0.002 p.p.m. of phenol

Cl, p.p.m.	0.100	0.150	0.201	0.251	0.301	0.351	0.402	0.503	0.603	0.703	0.804	1.01
Taste—45 min.	none	?	I	s. I	tr. I	?	tr. Cl	Cl	Cl	Cl	Cl	Cl
18 hrs.	none	?	tr. I	I	tr. I	?	none	none	none	?	tr. Cl	Cl
Odor —45 min.	none	?	tr. I	tr. I	tr. I	Cl	Cl	Cl	Cl	Cl	Cl	Cl
18 hrs.	none	?	?	?	none	none	none	none	none	none	?	Cl

Taste conditions when using Lake Ontario slow sand filtered water with varying doses of chlorine and phenol—continued

0.0002 p.p.m. of phenol

Cl, p.p.m.	0.099	0.149	0.198	0.248	0.297	0.347	0.396	0.495	0.594	0.693	0.792	0.890
Taste—45 min.	none	none	none	none	none	none	?	tr. Cl	Cl	Cl	Cl	Cl
18 hrs.	none	none	none	none	none	none	none	none	?	?	?	Cl
Odor—45 min.	none	none	none	none	?	?	?	tr. Cl	Cl	Cl	s. Cl	Cl
18 hrs.	none	none	none	none	none	none	none	none	none	none	tr. Cl	Cl

Taste conditions when using Lake Ontario slow sand filtered water with low doses of chlorine and varying doses of phenol

0.050 p.p.m. of chlorine

Phenol, p.p.m.	0.002	0.004	0.005	0.007	0.009	0.010
Taste—45 min.	none	none	none	none	none	none
18 hrs.	none	none	none	none	none	none
Odor—45 min.	none	none	none	none	none	none
18 hrs.	none	none	none	none	none	none

0.075 p.p.m. of chlorine

Phenol, p.p.m.	0.002	0.004	0.005	0.007	0.009	0.010
Taste—45 min.	none	none	none	none	none	none
18 hrs.	none	none	none	none	none	none
Odor—45 min.	none	none	none	none	none	none
18 hrs.	none	none	none	none	none	none

0.190 p.p.m. of chlorine

Phenol, p.p.m.	0.002	0.004	0.005	0.007	0.009	0.010	0.012	0.014	0.016	0.017
Taste—45 min.	none	none	?	?	tr. I	tr. I	tr. I	L	l	s. I
18 hrs.	none	?	tr. I	tr. I	I	s. I	s. I	s. I	s. I	s. I

0.205 p.p.m. of chlorine

Phenol, p.p.m.	0.004	0.010	0.017	0.023	0.028	0.033	0.038	0.043	0.049	0.054	0.059	0.064
Taste—45 min.	none	tr. I	I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I
18 hrs.	tr. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I
Odor—45 min.	?	tr. I	tr. I	I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I
18 hrs.	tr. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I

Experiments made to determine if addition of lime would remove iodoform taste

	Col. 1	*Col. 2*	*Col. 3*	*Col. 4*	*Col. 5*	*Col. 6*	*Col. 7*	*Col. 8*	*Col. 9*	*Col. 10*	*Col. 11*
Phenol, p.p.m.	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Cl, p.p.m.	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205
Taste and odor, 45 min.	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I	s. I
Cl added, p.p.m.		0.513									
Lime added, p.p.m.			37	45	52	60	67	75	82	90	97
Taste and odor, 2 hours	s. I	Cl	tr. I	?	?	?	?	?	?	?	?
20 hours	s. I	tr. Cl	s. I	I	I	I	I	I	I	I	I

Note: Column 2. Excess chlorine was applied to the water after the iodoform taste had developed. It will be observed that the iodoform taste was removed and a chlorinous taste resulted.

Column 5. The amount of lime applied (52 p.p.m.) was the theoretical amount necessary for removal of temporary hardness.

Column 11. This sample was filtered through three feet of sand. Filtrate tasted very strongly of iodoform. (Sample was filtered after the experiment had been completed.)

?, Doubtful.
tr., Trace.
s., Strong.
I., Iodoform.
Cl, Chlorinous.

were obtained when treating Lake Ontario water. In other waters, with varying chemical contents, different ranges might be recorded. The extensive nature of the figures makes a summary difficult. Briefly, it may be stated, that applied chlorine in doses up to 0.1 p.p.m. does not produce taste in combination with phenol, when this latter substance is present in quantities up to 0.015 p.p.m. Doubtful tastes may occur when chlorine is added in amounts between 0.135 and 0.150 part with phenol present up to 0.015 p.p.m. The critical dosage range occurs when chlorine is added in amounts between 0.175 and 0.4 p.p.m., with phenol ranging between 0.002 and 0.017 p.p.m. An actual combination of 0.22 part of chlorine and 0.007 part of phenol caused a water which both tasted and smelt badly of iodoform. In most of the experiments the taste, when it had once developed, became steadily worse, and in one instance after ten days was still pronounced. Chlorine applied in doses in excess of 0.65 part per million completely eliminated the iodoform taste, when phenol was present up to 0.017 p.p.m., but a faint chlorinous taste was left. In this series of experiments, involving several hundred tests, two definite points were established, first, that, in the presence of small amounts of phenol, an iodoform taste developed when 0.175 p.p.m. of chlorine was added, and, second, the taste persisted until the amount of applied chlorine reached a dosage of 0.65 p.p.m. Having demonstrated that chlorine in excess would take out the iodoform taste, experiments were made to see if increased doses of phenol would act in a similar manner. Chlorinated water containing 0.2 part of chlorine were treated with phenol in doses ranging between 0.010 and 0.064 p.p.m. The water thus treated was almost undrinkable, both tasting and smelling of iodoform. Before passing to other considerations, it should be stated that work carried out in Toronto confirms Houston's work in England, namely, that excess chlorine will completely remove iodoform taste. Assuming, therefore, that the excess chlorine treatment could be successfully applied to most supplies where tastes and odors occur, the problem would narrow down to one involving the determination of the amount of chlorine necessary and the subsequent removal of excess chlorine. Where aeration is possible de-chlorination would in most cases be unnecessary. This would be dependent, of course, upon the amount of chlorine originally applied and absorbed. Radical changes, such as excess chlorine treatment involves, will necessarily alter certain operating conditions, as filtration and steriliza-

tion processes. In connection with these, excess chlorine taste and odor could be removed without affecting the quality of the effluent by chlorination prior to filtration. Filters of any kind have remarkable chlorine absorption powers, due in part to their retention of organic matter. For various reasons engineers do not favor this practice, but the writer sees no reason, particularly where mechanical plants are involved, why chlorine could not be applied to the water after sedimentation and prior to its passage through the filters. This would apply, of course, only at times when the excess chlorine system was in use for relieving taste conditions. At Toronto, chlorination prior to filtration has been found to work efficiently and to give satisfactory results. No attempt has been made to use the excess chlorine treatment, but it will in all probability be tried out this summer. Laboratory experiments have demonstrated, however, that filtration does decrease the iodoform taste, and, if the application of chlorine may be so controlled that this taste is not allowed to develop, there should be no reason why the chlorinous taste could not be removed by application before filtration. The removal of excess chlorine by chemical reagents depends entirely upon local conditions. If the location of plant and the quality of the water are favorable, there is no reason why this system could not be undertaken, if it is borne in mind always that technical supervision is essential. The success of the treatments has been demonstrated by Houston.

Recently, the removal of the iodoform taste by excess lime, has been tried in Toronto. While the experiments are not yet sufficiently advanced, preliminary observations are not favorable. It was found, however, that the taste was reduced, but not eliminated, when using large quantities of lime. The combination of the characteristic taste produced by excess lime in water, together with the iodoform taste, rather masked the true taste. Three separate observers were able to detect the iodoform taste after a twenty hour contact period. Water treated with chlorine, phenol, and lime, and having a doubtful taste, was passed through a rapid sand filter, when a pronounced iodoform taste resulted, thus confirming the opinion previously expressed that lime only masked the iodoform taste. Taste occurring in the treated water at a temperature of 60°F. was less pronounced than at 45°F.

The experiments as conducted by the Milwaukee Sewerage Commission under Hatton and Copeland and described in the 7th Annual

Report of the Commission are of particular interest. Ammonia condensation liquor was found to contain as much as 0.144 per cent of phenol (carbolic acid). In the experiments with ammonia condensation liquor, containing 0.078 per cent of phenol and other taste producing compounds, it was shown that one part of the liquor produced a taste in 40,000 parts of chlorinated Lake Michigan water. The a.c. liquor was added to sewage entering an aeration tank in quantities ranging between 0.8 and 9.1 per cent of the sewage flow. No taste of consequence was delivered in the effluent except on one or two occasions. At such times the taste was so slight that, when the effluent was diluted with lake water, no taste could be noticed in the diluted sample. The conclusions were that, under warm weather conditions, the activated sludge process of sewage purification will remove the carbolic acid taste in sewage, which contained ammonia condensation liquor equal to 2 per cent of the sewage flow. For that reason it is concluded that the sewage disposal plant should protect the water supply from taste produced by ammonia condensation liquors discharged into the sewers. The absence of taste in many cities during the summer months might be linked up also with this condition, as, where industrial wastes are discharged into sewerage systems, marked seasonal biological activity occurs, which may have much to do with taste prevention.

In conclusion, the writer is strongly of the opinion that if industrial wastes are the real cause of taste occurring in chlorinated water, the best and surest remedy would be the prevention of stream pollution. In some states and provinces laws are in existence which, if enforced, would put an end to the discharge of obnoxious wastes into streams from which public water supplies are drawn. It seems only just that the burden should be placed upon the manufacturers. It is hoped that, if the existing laws cannot be enforced, future provision will be made whereby the burden of preventing stream pollution will be placed upon those directly responsible.

Rudolph Thompson, Assistant Chemist of the Toronto Filtration Laboratory, has been closely associated with the writer in the whole of the investigations recently made in connection with the occurrence of taste in chlorinated water.

WATER CHLORINATION CONTROL IN VIRGINIA[1]

By Linn H. Enslow[2]

The following description of the method of chlorine control at water works, as practiced in Virginia plants, is intended to show how successfully chlorine may be applied at all times to waters, in the proper quantity to remove dangerous bacteria and yet give no objectionable tastes, odors or noticeable increase in corrosiveness. For practical service a description of the apparatus required and the directions necessary for its use are included.

The proper and efficient control of chlorination of water supplies is exceedingly simple. No test for the chlorine "*absorption factor*"[3] need be made unless this is desired as a matter of interest or for study of the characteristics of a particular water. It is no longer necessary to know the rate-of-flow of the water being treated or the rate-of-discharge of chlorine gas. Where the method of control is employed efficiently, it is no longer a necessity to know the strength of hypochlorite of lime. The only essential to the success of the control is that the individual makng it be not color blind and that he exhibit a willingness to make the test as often during the day as necessary. Chlorine control by the test herein discussed is practiced in twenty-eight plants in Virginia. In sixteen of these neither the superintendent nor the operators have had any training whatever in chemistry. The simplicity of the test appeals to all who have seen it made.

EQUIPMENT AND DIRECTIONS FOR USE

Having carefully considered all tests at present applicable to the estimation of free chlorine present in small quantities in water it was decided to make use of the well known ortho-tolidine test given in the Standard Methods of the American Public Health Association.

[1] Presented before the Philadelphia Convention, May 18, 1922.

[2] Division of Engineering, State Department of Health, Richmond, Va.

[3] Chlorine Absorption and the Chlorination of Water, Wolman and Enslow, Jour. Ind. and Eng. Chem., March, 1919.

Water Chlorination Control by the Absorption Method, Wolman, Eng. News-Record, April 14, 1921.

The Laboratory of this Division keeps on hand standard color solutions prepared from potassium bichromate and copper sulphate and also ortho-tolidine solution. There are only two stock color solutions. No. 1 is prepared to represent the color produced by 0.1 p.p.m. and No. 2 that produced by 0.2 p.p.m. free chlorine, when ortho-tolidine solution is added to a water sample containing these

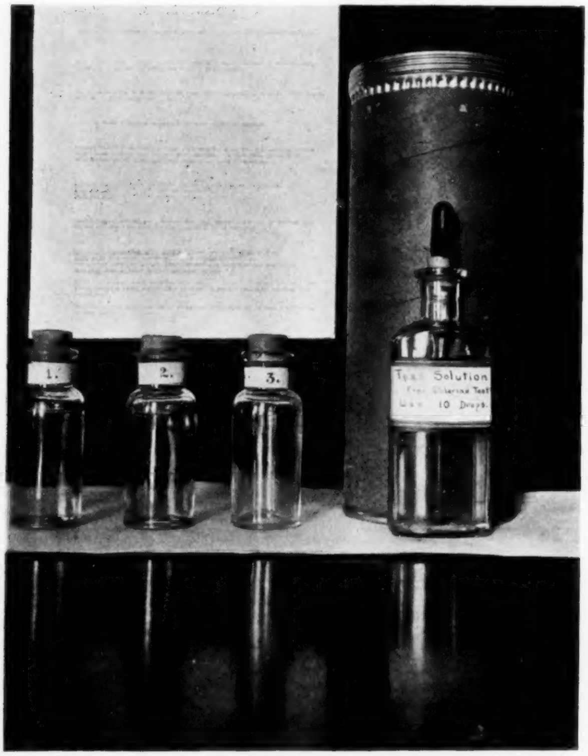


FIG 1

quantities of chlorine. As often as necessary, small bottles (about 50 cc. capacity) are filled with the standard color solutions and an eight ounce bottle, equipped with a stopper holding an eye-dropper, is filled with the ortho-tolidine solution. These, together with a third empty bottle of the same size and tint of glass as the two holding the color standards, constitute the "outfit," which is packed in a mailing carton for shipment to any plant where needed. The

third bottle is intended for the water sample collected for the test, to indicate whether the chlorine dose is correct. Below is a copy of the directions supplied with the testing outfit. The second set of instructions is intended for framing or otherw'se posting near the chlorination equipment, for convenience of new operators or others not entirely familiar with the test. The complete "outfit" is shown in figure 1, with instructions in the background. Wherever possible, we prefer to have someone thoroughly familiar with the test show the operators the exact details. The mere fact that it is a chemical test will frighten some and it is highly desirable, therefore, in order to avoid the likelihood of the test not being used, to demonstrate its simplicity first and to give the detailed instructions later.

Test for free chlorine in chlorinated waters

Apparatus: 1 empty bottle for collecting sample for comparison with standards; 1 bottle of ortho-tolidine solution. 1 dropping stopper or eye dropper (to be used with bottle); 2 standard color solutions representing 0.1 parts and 0.2 part per million of chlorine; 1 blue-glass nitrogen electric lamp for night testing.

Sampling point: A tap on the system not more than 25 nor less than 5 feet beyond the point at which the chlorine enters the water. (Note: Size of tap is of no importance, but a long threaded nipple extending into the pipe to a point near its center will produce a more reliable sample than otherwise obtainable.)

Procedure

1. Open valve on tap and allow water to waste for a few seconds. Collect a pint or more of sample slowly in a *clean* glass jar or bottle. Whirl the water in the glass container to obtain a thorough mixing for a second or two.
2. With the aid of the dropping stopper or dropper add 5 drops of the ortho-tolidine solution to the empty sample bottle (No. 3).
3. Fill the bottle with the water sample collected in the jar, but do not overflow it.
4. Allow the bottle containing the chemical and water mixture to stand about five minutes in warm weather or ten minutes in cold weather. (Note: The time required to allow the mixture to stand is for a two-fold purpose. The first is in order that the reaction of the free chlorine on matter contained in the water treated may take place. The second is to allow time for the free chlorine remaining after the chemical reaction to combine with the chemical added to produce the color reaction.)
5. After standing the required time, compare the color produced in the sample (No. 3) with the two standards No. 1 and No. 2. The color should be darker than No. 1 but *not* darker than No. 2. If lighter than No. 1 the chlorine dose is too low and should be increased. If darker than No. 2 the dose should be decreased. (*Note:* At night it is necessary to compare colors under a pure white or a blue-white light.)

6. In case a test shows that a change of dose in either direction is necessary, first change the dose and then wait about 10 minutes after the change before making a new test to see if the dose is correct. This time is required to allow the new chlorine dose to become constant at the sample tap.

The importance of test

7. The test should be made *at least* every eight hours during constant rate of pumping or as often as the rate of pumping is changed.

The *most important* times at which to make the test at plants treating water that has *not* been filtered are three.

a. After rains or other disturbances that cause the water to become muddy or even slightly turbid. At such times the chlorine dose should be raised to almost double before making test. Should the test then indicate too heavy a dose, cut it down to a proper one. (Note: The presence of a small quantity of mud in the water will cause the color to appear darker than it really is. At such a time color in excess of No. 2 should be obtained as indication of an effective dose.)

b. If the water becomes considerably muddy the test is valueless. In such cases apply chlorine until the sample drawn has a distinct odor of chlorine after standing the required length of time and then shaken.

c. When the water shows signs of clearing up after the stream has "run down," the chlorine dose can be reduced by degrees and tests made to show whether the dose is correct.

8. The Engineering Division of the State Board of Health at Richmond, Virginia, should be notified at least two weeks before the bottle of chemical solution has been all consumed. The solution and new color standards will be supplied as often as necessary and without charge.

Chlorine dose control

(Outline to be posted at the sterilization station for convenience of operators.)

1. Open sample cock. Allow to run few seconds. Catch one pint or more in clean glass jar or bottle and whirl the water a second to mix.

2. Place 5 drops chemical solution from dropper bottle into sample bottle (No. 3). Fill bottle with water from sample jar.

3. Allow to stand 5 minutes in warm or 10 minutes in cold weather.

4. Compare sample with standard color solutions No. 1 and No. 2 by looking through them placed side by side above a white surface. A difference in color is more noticeable if looking through them at an angle from above.

Correct dose: Color is darker than No. 1 but *not* darker than No. 2.

Dose too low: Color is lighter than No. 1.

Dose too high: Color is darker than No. 2.

(*Note:* For night testing a pure white or a blue-white light, such as obtained from a blue-glass nitrogen filled Mazda lamp, is necessary.)

5. Change dose if necessary. Wait 10 minutes. Make a new test. If correct dose is not obtained keep changing the dose until it is correct.

6. *Raise dose immediately water gets muddy* and make test *after* raising.

Lower dose when water clears up. Make test *after* lowering.

Change dose immediately each time after changing pump rate and make test.

Make test each 8 hours whether necessary or not.

(*Note:* In case of muddy water to be chlorinated color test cannot be used. Increase chlorine until sample after standing 10 minutes smells of chlorine when shaken up.)

Caution: Keep standards out of direct sun-light when not in use, preferably in dark place. Order more test solution before supply gets low.

Engineering Division,
State Department of Health,
Richmond, Va.

We are convinced that the expense of supplying such outfits as often as necessary has been a thoroughly good investment of funds. The return is adequate to warrant its continuance.

A FEW FACTS CONCERNING CHLORINE CONTROL

As stated above, where high turbidity is encountered the test for residual chlorine is useless. Here the "nasal-control" must be used. Even then, as will later be shown, the effectiveness of chlorination falls down under certain conditions.

Certain spring waters of low organic content and high bi-carbonate of lime content will not stand a residual free chlorine content of slightly more than 0.1 p.p.m., without producing a slight odor of hypochlorous acid at the cold water taps and considerable odor at the hot water taps. Certain other waters have been treated to allow about 0.3 p.p.m. free chlorine to remain after 10 minutes and without any detectable odors or tastes resulting. The general average of waters in Virginia, however, will not safely stand more than 0.2 p.p.m. residual without danger of odors occurring at the service taps. We have selected, therefore, the most satisfactory range as that between 0.1 and 0.2 p.p.m. It might be added here that this same "outfit," with modified control, is being used for chlorination control of swimming pools and sewage disposal plants.

Prior to the institution of the test at water plants chlorine was considered like unto a dose of castor oil at many places. It was conceded at times as necessary. The citizens were concerned more with getting rid of chlorination and less in the matter of drinking a few bacteria. When the reports from the Health Department indicated dangerous pollution, up would go the chlorine dose and the taste with it. Perhaps in many instances the organic matter had gone down already in the water or the high water in the stream

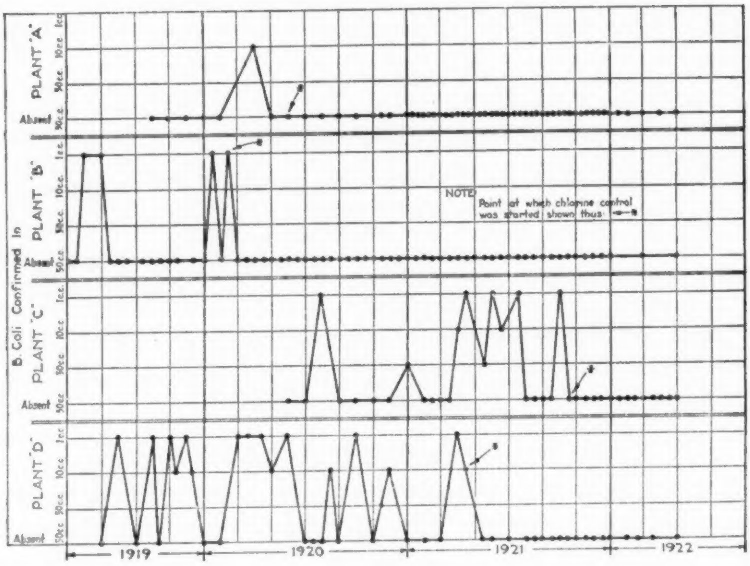

PLANT 'A'
PLANT 'B'
PLANT 'C'
PLANT 'D'
B. Coli Confirmed In
Absent
50cc
10cc
1cc
NOTE
Point at which chlorine control was started shown thus
1919
1920
1921
1922

FIG. 2a

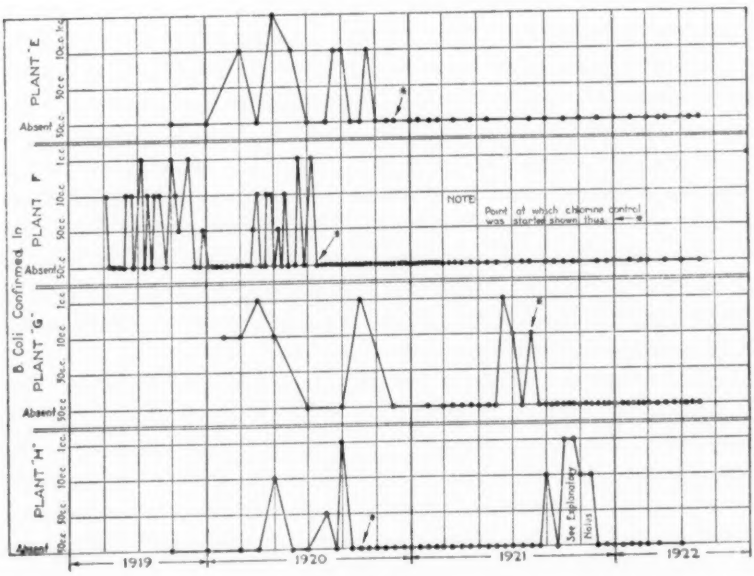

PLANT 'E'
PLANT 'F'
PLANT 'G'
PLANT 'H'
B. Coli Confirmed In
Absent
50cc
10cc
1cc
NOTE
Point at which chlorine control was started shown thus
See Explanatory Notes
1919
1920
1921
1922

FIG. 2b

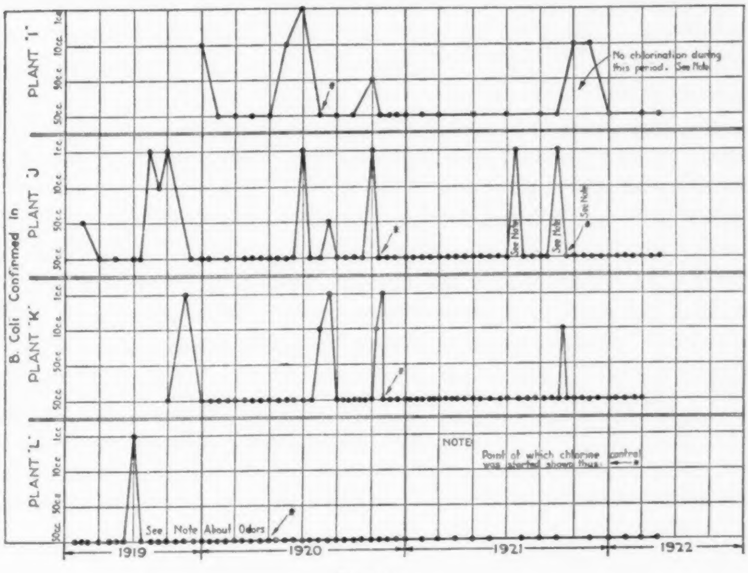

B. Coli Confirmed In
PLANT 'I'
PLANT 'J'
PLANT 'K'
PLANT 'L'
1cc
10cc
50cc
No chlorination during this period. See Note
See Note
NOTE: Point at which chlorine control was started shown thus:
See Note About Odors
1919
1920
1921
1922

FIG. 2c

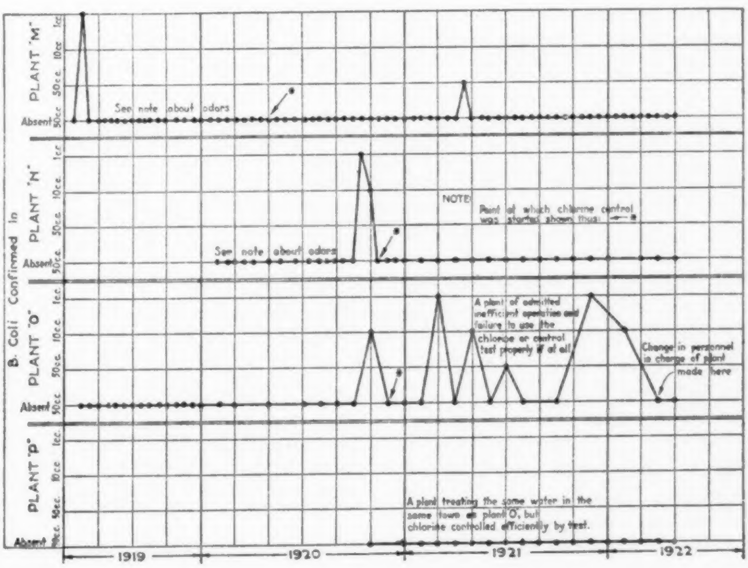

B. Coli Confirmed In
PLANT 'M'
PLANT 'N'
PLANT 'O'
PLANT 'P'
Absent
1cc
10cc
50cc
See note about odors
NOTE: Point at which chlorine control was started shown thus:
A plant of admitted inefficient operation and failure to use the chlorine or control test properly if at all.
Change in personnel in charge of plant made here
A plant treating the same water in the same town as plant O, but chlorine controlled efficiently by test.
1919
1920
1921
1922

FIG. 2d

had subsided before the laboratory report was received by the authorities. The chlorine dose was raised then at a time when unnecessary, with resulting complaints from the consumers about odors and from the superintendent of water works on corrosion of meters, etc. The complaints from consumers, and a possible word from the town "boss," resulted in a reduced chlorine dose, if not in its complete discontinuance for a while. The end result was the almost universal "ups and downs" of the curves showing the B. coli content of the water samples collected by local health officers or others. At certain times the sample showed practical sterility, to be followed immediately by the next sample containing B. coli present in 1 cc. or less. In almost every instance, except at efficiently operated filter plants, this was the case. It is gratifying to note, from the curves shown in figure 2, that with but one or two exceptions all of the twenty-eight plants, where chlorine in one form or another is being used, the B. coli content has remained constantly absent in 50 cc. quantities, since the adoption of control through use of the test here described.

The test, in addition to being used by operators, is used by city managers, superintendents and others on tap samples in their office, to check plant operation, provided the tap supplies water which received treatment not more than 8 hours prior to sampling.

The curves in figure 2 in certain instances call for explanatory remarks, as follows:

Arrow and asterisk indicate the date on which chlorine control was started through use of the outfit. In selecting plant records for presentation, those were taken which show the poorest results prior to or since the control-test was begun. Several filter plants are included, but none of them have trained operators, who had any knowledge of chemical tests prior to use of the control-test.

Plant C: Had no chlorination until the summer of 1921.

Plant D: Chlorine test outfit furnished in November 1920, but operator was holding dose too low because of fear of producing tastes. A demonstration was made in 1921, holding 0.2 p.p.m. free chlorine without tastes, which convinced him that this dose was satisfactory. Since this time results have been satisfactory.

Plant F: Characteristic of a plant where chlorine was insufficient in 1919. When raised too high odors and taste resulted, with a reduction to a point too low again. Since the test was begun no odor complaints have been registered and no B. coli have passed.

Plant G: Preferred to run excess chlorine with odors during latter part of 1920 and early 1921. Change of administration in spring of 1921 and chlorine

reduced to point too low. Since test began results have been satisfactory in all respects.

Plant H: An admirable example of where chlorine control was possible through test until early fall of 1921, when a new road was under construction along sides of stream fed by limestone springs and sink-holes. Heavy rains and resulting turbidity caused sudden appearance of b. coli in treated water. Representatives from this office visited plant. Chlorine raised to obtain more than 0.2 p.p.m. residual free chlorine with turbidity of about 150. Sample collected several hours later in town showed B. coli in 10 cc. Since this time the chlorine is increased to give a decided odor at taps in town during the run of muddy water. As a result of the sudden turbidity increases (sometimes to about 2000) and attendant factors of danger, the corporation owning this supply is now constructing a filter plant to care for the conditions under which chlorination alone is entirely unsatisfactory and unreliable.

Plant I: An example of what may happen where authorities fail to provide available extra chlorination equipment, which may be used in emergencies. In this case no attempt on the part of the operator had been made to provide even hypochlorite of lime and a barrel for emergencies. The control by test had proven very satisfactory. In the fall of 1921 the chlorinator began giving trouble. It finally went out of commission completely and no particular effort was made to obtain new equipment for several weeks. Conditions existing as stated were found by representative from this Department making a visit as a result of two samples showing B. coli present in 10 cc. Hypochlorite of lime treatment began immediately thereafter and continued until chlorinator could be sent away for repairs and returned to service.

Plant J: Another case of chlorinator troubles upon two occasions in the fall of 1921. Chlorinator in each case repaired on the ground as soon as possible, but there is no excuse for failure to provide emergency chlorination equipment and hypochlorite of lime or to have available duplicate liquid chlorine equipment. Almost universally the plants in Virginia now have emergency equipment, duplicate chlorinator, parts of same, or both. At this particular place, prior to advent of the control test, there were times when the consumers refused to drink the treated water because of the excessive chlorine dose. Springs of questionable quality were being used instead.

Plant K: Prior to adoption of control test at the plant the City Health Department had been making tests at the laboratory in town only, which was a result of a misunderstanding of the use of the test. Daily bacteriological examinations are made of tap samples. In the fall of 1920, the operator at the filter plant was provided with an outfit and tests were made there. After leaving the plant the water passes through a large open reservoir, which probably accounts for the single tap sample which shows B. coli present in 10 cc. quantities since control began.

Plant L: Treating a limestone spring water subject to sudden pollution after rains. Prior to use of test the chlorine dose during the majority of the time produced the hypochlorous acid odor at the taps. The residual at this plant is kept down to 0.1 p.p.m., or slightly more, with satisfactory results.

Plant M: Prior to adoption of control test complaints of odors were frequent.

Plant N: Same remarks as plant M.

Plant O: Plants O and P are treating the same water in the same town.

Plant P: Plant P, which produces efficient results, is owned by an industrial corporation. Plant O is owned by a municipality and until recently was poorly operated and managed, regardless of efforts on the part of this Division to obtain an improvement. Repeated warnings to the authorities, calling attention to the poor efficiency and careless operation of the plant, have had the desired effect. A change made in the personnel in charge of the plant was recently made. The "fall" in the B. coli curve to a point indicating effective chlorine control, if nothing more, is gratifying. The curves of plants O and P are purposely given to illustrate what may be accomplished with and without the proper chlorine control.

SUMMARY

An attempt has been made to describe a simplified method of chlorine dose-control adaptable to use by those without training in chemistry.

Diagrams have been given to show that an improved quality of water may be produced and that odors due to chlorine or hypochlorites *as such* may be eliminated through use of the control-test properly applied.

In treatment of water and sewage, it is no longer necessary to know the exact volume being treated nor the exact rate-of-feed of the chlorine in order that efficient treatment may result. The necessity of making tests to obtain the "chlorine absorption" factor for a given water no longer exists. A test outfit, non-fragile, compact, of simple make-up and manipulation, of practical value to waterworks personnel, health officers and others, has been assembled and supplied without charge at points of usefulness. Results obtained warrant the continuance of the practice of supplying such outfits or of replacing parts where necessary.

REPORT OF THE FINANCE COMMITTEE FOR THE FISCAL YEAR ENDING MARCH 31, 1922

Your Finance Committee presents the following report on the financial operations of the Association for the fiscal year ending March 31, 1922. The books of the Secretary and the Treasurer have been audited and found correct. All vouchers have been examined and verified. The details of the financial affairs of the Association as set forth in the respective reports of the Secretary and the Treasurer are in accordance with their books.

OPERATING INCOME AND EXPENSE

The Committee has examined and audited the books of the Treasurer and of the Secretary and has found them to be correct, and their cash balances to agree. For the reason that there are certain compensating receipts and expenses, such as reprints of authors' papers, binding cases, etc., representing initial outlays which later are returned, reports of the Secretary and of the Treasurer do not exactly agree, although both are correct. Your Committee has taken the figures as submitted by the Secretary, eliminating compensating expenses and repayments for use in this report.

The 1920-21 Finance Committee recommended a budget allowance of $18,000.00 for the operating expenses for the fiscal year 1921–22, which was approved by the Cleveland Convention with the proviso that committee expenses should be kept to a minimum, if operating receipts were less than anticipated. This budget was an increase of $2,863.88 over the actual disbursements of the fiscal year 1920–21. The actual expenses for the past year as shown by the Secretary's report were $14,570.32, while the operating income as shown by the same report was $17,432.42, which makes a net profit from operation of $2,862.10. At the beginning of the last fiscal year on April 1, 1921, the cash balance on hand was $234.74. At the close of the year it was $3,080.34, showing an increase of $2,845.60. The difference of $16.50 is explainable by the fact that certain expenditures were made as usual by the Secretary's office for binding cases, etc., that are carried on the merchandise account. These items are not charged

to the Profit and Loss Account as they represent stock on hand. Your Committee would recommend that separate books be kept for these accounts under the head of Property Accounts, and all expenditures and receipts for binding cases, reprints, authors' copies, etc., be kept in this Account. In this way a close check could be kept on the miscellaneous receipts and disbursements, and the proper charge for reprints, authors' copies, binding cases, etc., be easily determined. Especially is this desirable as it is expected that the Association will shortly make an investment in office equipment.

Summarized statement of accounts for the fiscal year ending March 31, 1922.

Balance on hand in bank April 1, 1921	$234.74	
Net income from all sources	18,002.44	
Total income		$18,237.18
Total operating expenses	15,140.34	
Disbursements for merchandise now on hand	16.50	
Balance on hand in bank April 1, 1922	3,080.34	
		$18,237.18

PERMANENT INVESTMENT FUND

There are now in the hands of the Treasurer, by authority granted the Finance Committee by the Executive Committee, certificates constituting the Permanent Investment Fund of the Association as follows:

	Par value	
Four $1000 Dominion of Canada 5 per cent Bonds due April, 1931	$4,000	
Four $500 U. S. 1st Liberty Loan Bonds 3½ per cent	2,000	
One $1000 U. S. 2nd Liberty Loan Bonds 4¼ per cent	1,000	
Two $1000 U. S. 3rd Liberty Loan Bonds 4¼ per cent	2,000	
Two $1000 U. S. 4th Liberty Loan Bonds 4¼ per cent	2,000	
One $1000 U. S. Victory Loan Bond 4¾ per cent	1,000	
		$12,000.00

In view of the rapid appreciation in value of the above Bonds during the past year and their approaching maturity, your Committee believes that they could be disposed of to advantage and the

proceeds invested in high-grade bonds of longer terms, and possibly at a higher rate of interest. Any new or reinvestment of funds should be only in bonds which are legal for investment by savings banks of the State of New York.

Your Committee further recommends that the Permanent Investment funds be maintained at a minimum of $12,000 with a maximum of $20,000.

BUDGET ALLOWANCE AND DISBURSEMENTS

Last year's budget total of $18,000 was sufficient to cover all needs and all items came within the amount allowed, with the exception of convention expenses. The actual convention expenses were $1,015.42 exceeding the budget allowance by $215.42. Of this amount $114.90 was charged to office expenses, $57.11 to contingencies and payment deferred on $43.41. Your Committee has analyzed the convention expenses and of the total expenses $512.64 were expended on printing and postage previous to the convention; $250.00 for an official reporter; $158.73 for rent of lantern and motion picture apparatus, desk and typewriter and the purchase of stationery at the convention; and a balance of $94.42 for signs, telephones, etc. Inasmuch as the annual convention is the one meeting which the most of our members attend, your Committee believes that any reasonable expenditures, which will increase the attendance and add to the convenience of those who are there, are warranted. Your Committee, therefore, has increased the convention item this year sufficiently to pay the $43.41 unpaid from the Cleveland Convention.

The item for Committee expenses was much too large, but this was due to the fact that the expenses of the Standardization Committee were much smaller than anticipated. Their work has now been organized and during the coming year their expenses will be much greater.

No transfer of funds from one item to another was necessary during the year.

The following is a statement of budget allowances and disbursements for the past fiscal year:

Item	Budget	Disbursements
1. Convention expenses	$800.00	$800.00
2. Office expenses	1,200.00	1,198.58
3. Committee expenses	2,800.00	289.01
4. Section expenses	900.00	809.48
5. Insurance	75.00	58.45
6. Salary of Secretary	800.00	800.00
7. Salary of Editor	900.00	900.00
8. Printing JOURNAL	8,000.00	7,165.40
9. Contingencies	245.00	245.00
10. Salary Assistant to Secretary	1,200.00	1,200.00
11. Rent of office	1,080.00	1,080.00
	$18,000.00	$14,545.92

EXPENSES FOR THE CURRENT FISCAL YEAR

Your Committee has given careful consideration to the financial needs and resources of the Association for the coming year and has conferred with the Executive Committee upon same and by their order recommends the following budget for the year 1922–23.

Convention expenses	$900.00	
Office expenses	1,200.00	
Committee expenses	2,250.00	
Section expenses	1,080.00	
Secretarial expenses	3,500.00	
Salary of Editor	1,200.00	
Printing of JOURNAL and Supplement	8,500.00	
Rent of office	1,080.00	
Insurance	75.00	
Contingencies	315.00	
		$20,100.00

By resolution of the Executive Committee the Finance Committee recommends the abolition of the office of Assistant Secretary, and that $3500 be allowed for secretarial expenses, with the understanding that from this sum the Secretary will employ such assistance as he may need.

While the expenses of the Standardization Committee were small last year, the Chairman has asked for $2000 for the coming year, and committee expenses have therefore been placed at $2250.

Last year the allowance for Editor was reduced from $1200 to $900 per year on the recommendation of the then Editor. Since that time a new Editor has been appointed and serves at the rate

of $1200 per year. Your Committee has, therefore, increased the item for Editor to $1200.

AVAILABLE RESOURCES FOR THE FISCAL YEAR 1922-23

On April 1, 1922, there was a total membership of 1608 divided as follows: Active, 1334; Corporate, 118; Associate, 153; Honorary, 3. This is a total increase of 68 for the year.

Based on the above, the income would be as follows:

Total from annual dues	$12,773.00	
Estimated initiation fees	1,200.00	
Estimated income from advertisements and subscriptions	3,300.00	
Interest on investments and deposits	750.00	
		$18,023.00
Cash on hand April 1, 1922		3,080.14
		$21,103.14

Your Committee believes this a minimum estimate of income.

The Treasurer's Report shows a balance of $957.32 in the Electrolysis Investigation Fund. The Treasurer is under bond for $10,000 in accordance with the order of the Executive Committee, and this bond is in the custody of the Chairman of the Finance Committee.

No bond has ever been given by the Secretary and your Committee recommends that the Secretary be bonded for $2000.

Your Committee further recommends that the Executive Committee designate those persons whose expenses to the convention are to be paid by the Association.

Your Committee further recommends that no expenses properly chargeable to any other item of the budget shall be chargeable to the contingent fund. and that all items charged against the contingent fund for the ensuing year be listed in the next report.

No provision has been made in the budget for the purchase of the office equipment now being used by the Secretary, as your Committee feels this is properly chargeable against the Permanent Fund of the Association.

J. Walter Ackerman.
Charles R. Henderson.
George C. Andrews,
Chairman.

ANNUAL REPORT OF THE TREASURER

I submit herewith my report as Treasurer of the American Water Works Association for the year ending March 31, 1922.

The funds of the Association are on deposit with the United States Mortgage & Trust Company at their branch located at 73rd St. and Broadway, New York City. This bank was selected by vote of the Executive Committee.

Receipts and disbursements, April 1, 1921–March 31, 1922

Receipts:		
Balance on hand April 1, 1921	$234.74	
Received from J. M. Diven, Secretary	17,850.05	
Interest on deposits	127.56	
Interest on investments	530.00	
Total		$18.742.35
Disbursements:		
Expended in payment of vouchers, aggregating 116 in number, and comprising vouchers No. 1098 through 1213A. Checks bearing the same numbers as the vouchers have been drawn, with the exception of those vouchers which cover the deductions made by the bank for charges on check collections	$15,376.49	
Troy Trust Co. debit slips	8.44	
For one check which was returned by the U. S. Mortgage & Trust Co. with the notice that it had been deducted from the account	12.00	
Exchange on checks for month of March	0.40	
		15,397.33
Balance April 1, 1922		$3,345.02

The cash balance at the close of business March 31, 1922, as shown by the attached certificate of the U. S. Mortgage & Trust Co. was		$3,562.75
From this balance there should be deducted the following for unreturned checks:		
Voucher 1207	$52.67	
Voucher 1208	32.15	
Voucher 1210	100.00	
Voucher 1212A	19.41	
Voucher 1213A	13.50	
		217.73
		$3,345.02

Secretary Diven advises me that in his report there are certain differences which are as follows:

Treasurer's cash balance	$3,345.02	
Secretary's cash balance	3,080.34	
Difference		$264.68
Vouchers included in the secretary's expenditures but not received by the treasurer by March 31, 1922:		
No. 1212	$157.75	
No. 1213	47.15	
No. 1214	8.35	
No. 1215	39.30	
		$252.55
Bank transactions not included in secretary's report:		
Interest for February	$7.12	
Interest for March	5.41	
Total	$12.53	
Bank deduction for check collections for March	.40	
Difference		12.13
Total		$264.68

Mr. J. M. Caird was Treasurer from April 1, 1921, to June 16, 1921, and the report covers the transaction of both Mr. Caird and the present Treasurer.

The receipted vouchers have been returned to the Secretary. The cancelled checks and deposit slips with the book of the Treasurer are available for audit.

The permanent fund has not changed during the year, and consists of the following:

4—$1000 Dominion of Canada 15 year 5 per cent bonds	$4,000.00
4— 500 U. S. Lib. 1st, 3½ per cent bonds	2,000.00
1— 1000 U. S. Lib. 2nd 4¼ per cent bond	1,000.00
2— 1000 U. S. Lib. 3rd 4¼ per cent bonds	2,000.00
2— 1000 U. S. Lib. 4th 4¼ per cent bonds	2,000.00
1— 1000 U. S. Victy. 4¾ per cent bond	1,000.00
Par value of permanent fund	$12,000.00
Interest on permanent fund	$530.00

The treasurer received no salary, and is under $10,000 bond, which has been placed by the Finance Committee.

Respectfully submitted,

Wm. W. Brush,
Treasurer.

ANNUAL REPORT OF THE TREASURER FOR ELECTROLYSIS FUND

I submit herewith my report as Treasurer of the American Water Works Association for the electrolysis fund, year ending March 31, 1922.

The funds of the Association are on deposit with the United States Mortgage & Trust Co. at their branch located at 73rd St. and Broadway, New York City.

Receipts and Disbursements, April 1, 1921–March 31, 1922

Receipts:		
Balance on hand April 1, 1921	$950.55	
Received from J. M. Diven, Sec'y	276.00	
Interest on deposits	12.88	
Total		$1,239.43

Disbursements:

Expended in payment of vouchers, aggregating 6 in number, and comprising checks 12 through 17.....	$282.11
Balance April 1, 1922..............................	$957.32

WM. W. BRUSH,
Treasurer.

DISCUSSIONS

WOOD PIPE AND WATER HAMMER

Mr. Ledoux has indeed contributed noteworthy observations[1] concerning wood pipe. It is papers of this nature which greatly assist in clearing away the skepticism regarding this type of pipe which I have found prevalent among both laymen and engineers.

There are, however, two matters pertaining to wood pipe which were not mentioned. There are instances where the staves have received a creosote treatment and it would be interesting to know the extent of the use of this treatment, together with its advantages.

Where a pipe is under constant pressure cresote treatment would hardly seem necessary or even desirable. This is in view of the fact that the manufacturers of stave pipe state that one of the essentials to the life of the pipe is that the stave shall be thoroughly saturated, so that the outside of the stave is moist. There are undoubtedly cases where partial penetration of creosote would be advantageous.

The other matter concerns the swelling effect of the staves on the bands. Do the manufacturers take this into consideration in designing bands or not?

Mr. Ledoux also brings to our attention the fact that the effect of water hammer is an ever present problem.

An elementary consideration of water hammer may lead to a better understanding of the more complicated investigations.

Water hammer may be explained with some degree of clearness by the analogy between the resilience in a bar of steel under pressure and a column of water in a penstock.

It can be seen that the amount of work done in stressing a bar is

$$K = 1/2\, Pe$$

also $$P = aS \text{ and } e = Sl/e$$

Therefore $$K = 1/2\, S^2/E\, al \qquad (1)$$

where P = total stress

e = elongation

[1] Journal, July, 1922, page 549.

a = cross section area
S = unit stress
l = length

This represents the work stored within the body.

Now in the penstock there is a column of water having a certain amount of work stored up in it, equal to

$$K = \frac{1}{2}\frac{Wv^2}{g} = \frac{1}{2}\frac{walv^2}{g} \tag{2}$$

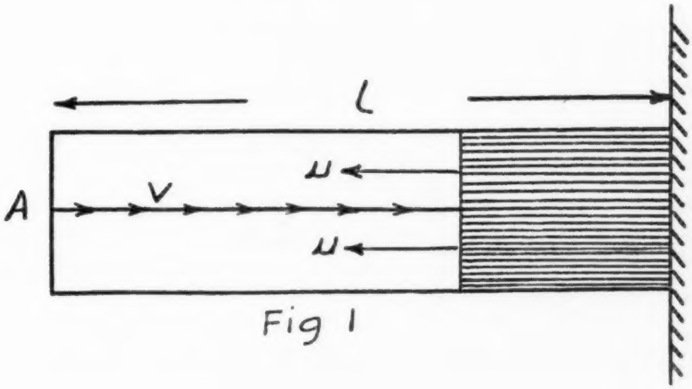


Fig 1

Equating (1) and (2) we have

$$S = v\frac{Ew}{g} \tag{3}$$

This represents the dynamic unit pressure produced by the retardation of the velocity, where E equals modulus of elasticity of the water, usually taken at 294,000 pounds per sq. in.

It is better to express the value of E in terms of the velocity of water hammer waves.

$$u = \sqrt{\frac{Eg}{w}}$$

To establish this formula we again use as a comparison a steel bar. In figure 1 the bar of steel is assumed to have struck the wall as shown and immediately there starts a wave of retardation of the molecules

toward the end A as indicated by the arrows. When the wave has reached the end A the bar has been shortened an amount

$$e = vt \tag{4}$$

e = total shortening.

Again there is set up in the bar a stress energy as previously shown equivalent to

$$K = \tfrac{1}{2}\frac{S^2}{E}al \tag{5}$$

From (4) we obtain the unit shortening

$$r = \frac{vt}{l}$$

as $E = \dfrac{S}{r}$ $\qquad r = \dfrac{S}{E}$

Substituting in (5) we have

$$K = 1/2\ E\ r^2\ \mathrm{al}$$

then substituting the value of r we obtain

$$K = \tfrac{1}{2}E\frac{v^2t^2}{l}a \tag{6}$$

Equating this to the kinetic energy of the bar (5) we have

$$\frac{wl}{g} = \frac{Et^2}{l} \quad \text{or} \quad \frac{l^2}{t^2} = \frac{\mathrm{Eg}}{\mathrm{w}}$$

But $\dfrac{l^2}{t^2} = u^2$ so that $u^2 = \dfrac{Eg}{w}$

where u represents the wave velocity

$$\text{or } u = \sqrt{\frac{Eg}{w}} \quad \text{or} \quad E = \frac{u^2w}{g}$$

This value of E may be substituted in (3) and by using a value of 4670 for u and dividing w by 144 to obtain proper units the formula may be further reduced.

$$S = \frac{wu}{g} v$$

This represents the dynamic unit pressure due to retardation. To estimate the excess of water hammer pressure over the static pressure, it is necessary to take into consideration the initial and final pressures.

Then $$S = Z + h - p$$

where Z = excess water hammer
h = static pressure, no flow
p = initial dynamic pressure, water flowing.
Solving for Z and substituting above value of S we have

$$Z = \frac{wu}{g} v + p - h$$

This does not take into consideration the energy expended in stretching the metal but is on the safe side since it gives a larger value for water hammer.

HARRY S. PAYROW.[2]

BROM THYMOL BLUE AND PHENOL RED COLOR STANDARDS DO NOT DETERIORATE VERY RAPIDLY

It is the opinion of many who use color standards for the determination of hydrogen ions that the standards deteriorate very rapidly. This has been our experience with some indicators, but others seem to be more permanent. The laboratory at the Montebello Filters, Baltimore City Water Department, is in possession of some of the tubes of a set of brom thymol blue and phenol red standards prepared for Wolman by Miss Lillian Burroughs of the Maryland State Department of Health, in May 1920; and others of the same indicators prepared by the LaMotte Chemical Products Co. in July 1921. These tubes have been kept in a dark room all the time, except for a few minutes each day when in use. They were replaced by other standards after about 6 months use, and since then have been stored in a dark room. The following tables should be of interest:

[2] Assistant Professor of Civil Engineering, Lehigh University, Bethlehem, Pa.

Table showing the comparison of color standards with standards newly prepared

NEW STANDARDS PREPARED JULY, 1922	LA MOTTE STANDARDS, PURCHASED JULY, 1921	MARYLAND STATE DEPT. OF HEALTH, PREPARED MAY, 1920
	Brom thymol blue	
6.0	6.0	Faded
6.2	Broken	6.0
6.4	6.4	Broken
6.6	Broken	6.4
6.8	6.8	6.7
7.0	7.2	6.8
7.2	7.2	7.0
7.4	7.3	7.2
7.6	7.4	7.2
	Phenol red	
7.0	Faded	
7.2	7.2	
7.4	Broken	Broken
7.6	7.6	7.3
7.8	7.8	7.6
8.0	8.0	8.0
8.2	8.2	8.2
8.4	8.4	8.4

In some instances the color fades or changes to a different shade from that of new standards. This is more noticeable in the yellow color of the brom thymol blue standards. In such cases the standards are no good, but when the change is merely in pH value there is no objection to marking the true value and using them again.

JOHN R. BAYLIS.[3]

[3] Principal Sanitary Chemist, Baltimore City Water Department.

SOCIETY AFFAIRS

THE ANNUAL CONVENTION

Following the custom of recent years, the official opening of the Forty-Second Annual Convention on Tuesday, May 16, 1922, at the Bellevue-Stratford Hotel, Philadelphia, Pa., was preceded by informal sessions on Monday afternoon and evening. Executive and standing committees and special groups held their meetings on Monday. The Council on Standardization, in particular, attracted considerable attendance at its preliminary discussions of auxiliary committee work.

On Monday evening, the exercises were opened in the ballroom of the Bellevue-Stratford by an address of welcome by E. J. Cattell, the city statistician of Philadelphia. This interesting speech was followed by the annual presidential address[1] by President Edward Bartow. The remainder of the evening was spent by members and guests in dancing.

Morning session, May 16. Presiding officer, President-Elect Cramer. The following list of officers elected was read, since no opposition ticket had been presented: President, W. S. Cramer; vice-president, G. W. Fuller; treasurer, W. W. Brush; trustee, G. W. Batchelder; trustee, J. W. Ellms.

The following order of business and papers took place:

Report of Publication Committee,[2] read by R. B. Morse, chairman, and adopted for printing in the Journal.

Report of Finance Committee,[3] read by G. C. Andrews, chairman, and accepted.

Philadelphia Water Supply, Present and Proposed, by George W. Fuller; no discussion.

Fire Prevention and Fire Protection in Relation to Public Water Supply,[4] by Frank C. Jordan; discussion by Allen Hazen, Leonard Metcalf, John N. Chester, Dow R. Gwinn and the author. The

[1] JOURNAL, July, 1922, page 589.

[2] JOURNAL, July, 1922, page 627.

[3] See page 793 of the JOURNAL.

[4] See page 731 of this JOURNAL.

paper contained a resolution requesting the Association to affiliate with the National Fire Prevention Association. The resolution was referred to the Executive Committee for action, and this Committee recommended that, in view of the fact that it had before it similar invitations from other bodies, such invitations be declined for the present. Similar negative action was decided upon by the Executive Committee in the case of joining the American Construction Council.

Afternoon session, May 16. Presiding officer, President-Elect Cramer.

The following papers were presented:

Development of the Schoharie Watershed, Catskill Water Supply, by J. Waldo Smith; no discussion.

The Hetch Hetchy Water Supply,[5] by M. M. O'Shaughnessy; presented by Charles Gilman Hyde; no discussion.

The Construction of the Loch Raven Dam, by William A. Megraw; no discussion.

Twenty Years Filtration Practice at Albany, N. Y., by G. E. Willcomb; discussion by P. G. Bunting, Allen Hazen, W. H. Lovejoy and the author.

The election of the following members of the Nominating Committee was announced: District 1, J. J. Salmond; District 2, J. H. Caldwell; District 3, W. R. Edwards; District 4, D. R. Gwinn; District 5, J. Chambers; District 6, J. J. Hinman, Jr.; Chairman, B. C. Little, ex-president of the last convention.

Evening session, May 16. Presiding officer, President Bartow. Session under the auspices of the Water Works Manufacturers' Association. The following papers were read:

Dean Control of 20,000 H.P. of High Steam Pressure, with moving pictures, by Peter Payne Dean.

Underground Leakage and its Relation to Mains and Services, by Thomas F. Wolfe.

Pneumatic Pumping, Up to Date, by John Oliphant.

The ladies were entertained during the day with an automobile trip to Valley Forge, under the auspices of the Water Works Manufacturers' Association.

Morning session, May 17. Presiding officer, President Bartow. The papers read were:

[5] See page 743 of this Journal.

Report of Committee on Standard Form of Contract, by J. Waldo Smith, chairman; report accepted and committee continued.

Report of Council on Standardization,[6] by George W. Fuller, chairman; adopted.

At the request of the presiding officer, G. W. Fuller described the work planned by the newly-organized Advisory Committee on Water Supply Standards created by the U. S. Public Health Service to present recommendations as to methods and measures for determining upon a standard of quality for drinking water on interstate carriers. The Association has many of its members on this Committee and its coöperation is solicited in the work to be carried on in the succeeding year.

Mr. Durgin, representing Secretary of Commerce Hoover, then spoke on the work of the United States Standardization Council and pointed out the necessity and advantages of simplified practice. The speaker requested the coöperation of the Association in the campaign for standardization. The work in standardization of cast iron pipe manufacture was pointed out by Allen Hazen, and in meter construction by C. M. Saville. The message from Mr. Hoover was referred to the Council on Standardization for action.

The following papers were then read:

Report of Committee on Industrial Wastes in Relation to Water Supply, by Almon A. Fales, chairman; discussed by Charles Haydock, G. W. Fuller, Leonard Metcalf and Mr. Moses.

In the discussion of the report, a resolution was presented by C. Haydock, calling upon the Association to forward the report to governmental agencies with the request for national investigation. The resolution was referred to the Executive Committee, who transmitted it to the Committee on Industrial Wastes for consideration and report to the next Executive Committee.

Report of Committee on Watershed Protection, by T. DeL. Coffin, chairman; discussed by W. L. Stevenson and F. T. Kemble.

Problems in the Reforestation of Watersheds, by George R. Taylor.

Detroit was selected as the convention city for the meeting of 1923. San Francisco and Omaha were defeated competitors.

The following resolution, introduced by, D. R. Gwinn, was unanimously adopted:

[6] JOURNAL, July, 1922, page 632.

Resolved, by the American Water Works Association in convention assembled in the City of Philadelphia, that we recall with interest the valuable services rendered by Wm. Benedict Bull, of Quincy, Ill., now the oldest living Past President of this Association, and who presided at the Eleventh Annual convention held in Philadelphia in May, 1891, and that we now extend hearty congratulations and cordial good wishes to Mr. Bull, and the Secretary be requested so to advise him by wire during this session.

Afternoon session, May 17. The members and guests spent the afternoon session on a boat trip on the Delaware River, under the auspices of the Water Works Manufacturers' Association.

Evening session, May 17. Presiding officer, President Bartow. The papers read appeared in this order:

Some Observations Concerning Wood Pipe,[7] by J. W. Ledoux; discussed by J. E. Gibson, J. N. Chester, J. Chambers and the author.

Report of the Committee on Standard Specifications for Cast Iron Pipe and Specials, by F. A. Barbour, chairman; report adopted.

Experience with Cast Iron Water Pipe for Pressures Higher than Allowed by Current Specifications, by C. E. Inman; discussed by J. N. Chester, W. F. Wilcox, Leonard Metcalf and the author.

Improved Financial Condition of Water Works in the United States,[8] by Leonard Metcalf; no discussion.

The Editor of *Engineering News-Record*, E. J. Mehren, described the proposed activity of the American Construction Council and extended an invitation to the Association to become a member of the Council. The annual dues were stated as $100. The matter was referred to the Executive Committee for action. The Executive Committee recommended declining the invitation for the present.

The last paper of the evening was:

Centrifugally Cast Iron Pipe,[9] by Peter Gillespie.

Morning Session, May 18. (*Superintendents' Day*). Presiding officer, President Bartow. The following papers were presented:

Water Chlorination Control in Virginia,[10] by Linn H. Enslow; discussion by A. Wolman, E. Bartow, L. L. Jenne and the author.

Report of Committee on Physical Standards for Distribution Systems, read by G. G. Dixon, chairman; discussion by Allen Hazen and G. G. Dixon.

[7] JOURNAL, July, 1922, page 549.
[8] See page 685 of this JOURNAL.
[9] See page 703 of this JOURNAL.
[10] See page 783 of this JOURNAL.

Air and Relief Valves, by M. M. Borden.

Instances of the Value of a Sanitary Survey, by W. P. Mason.

Causes of Failure of Cast Iron Pipe, by F. A. McInness.

The meeting then turned to the discussion of special topics as follows:

Check Valves on Metered Services and their Damage by Hot Water, discussed by C. W. Sherman, D. R. Gwinn, E. E. Davis, E. T. Cranch and W. Luscombe.

Double Check Valves on Private Fire Services, discussed by D. R. Gwinn, S. H. Taylor, F. A. McInness and H. A. Burnham.

Scrap Lead as Make-Up for Pipe Joints, discussed by A. P. Folwell, D. R. Gwinn and F. A. McInness.

Protecting Mains Under Railroad Tracks, discussed by D. R. Gwinn, J. E. Gibson, W. Luscombe, and W. C. Hawley.

Pipe Jointing Compounds, discussed by D. R. Gwinn, W. Luscombe, W. C. Hawley, E. T. Cranch, J. E. Gibson, W. F. Wilcox, H. F. Cox, G. G. Dixon, J. A. Jensen, and S. H. Taylor.

Afternoon session, May 18. Presiding officer, President-Elect Cramer.

The topical discussion was resumed as follows:

Location and Spacing of Fire Hydrants, discussed by E. T. Cranch, W. S. Cramer, H. P. Bohmann, and D. R. Gwinn.

Use of Public Fire Hydrants for Street Washing, etc., discussed by C. M. Saville, W. S. Cramer, C. E. Davis, C. M. Crowley, A. B. Styles, and D. R. Gwinn.

Following these topical discussions, the papers named below were presented.

Equipment and Shop Facilities for Maintenance of Water Works Systems, by G. E. Cripps; discussion by W. W. Brush, B. C. Little, F. L. Sward, E. T. Cranch, C. W. Newell, W. S. Cramer, and C. M. Crowley.

Inorganic Matter Floating in Reservoirs, by J. E. Gibson.

Present Day Tars for Pipe Coatings, by W. R. Conard.

W. W. Brush then presented a paper prepared by Mr. Loeb of his organization on methods of prevention of tampering with meters, which was discussed by J. M. Diven, F. B. Nelson, J. Woolley and D. R. Gwinn.

A topical discussion on Service Pipes was taken part in by J. N. Chester, H. C. Crawford, D. R. Gwinn, H. P. Bohmann, J. E. Gibson, J. M. Diven, C. M. Crowley and A. B. Styles.

Cleaning Water Pipes Before Placing in Service, discussed by W. W. Brush, J. M. Diven and E. Bartow.

Size of Meters and Services, discussed by D. R. Gwinn, A. B. Styles, G. C. Gensheimer, W. S. Cramer, J. E. Gibson, W. W. Brush and W. Luscombe.

Evening session, May 18. Presiding officer, Past President Gwinn.

The following papers were presented:

Purification of Water for Industrial Purposes, by S. T. Powell; discussion by R. S. Weston.

Lime-Soda and Zeolite Water Softening, by A. S. Behrman.

Turbo-Centrifugal Pumps, by R. Waller.

The session was adjourned in order that the members might attend the smoker at the Bellevue-Stratford. The ladies were entertained at a card party in the same hotel.

Morning session, May 19. Presiding officer, President Bartow.

This session had been arranged as a joint session of the general convention with the Chemical and Bacteriological Section. The papers presented were as follows:

Plant Control of Chlorination by the Excess Chlorine Method as Employed in New York City's Water Supplies, by F. E. Hale; discussion by J. R. Baylis.

Responsibility of the Water Works Superintendent to Prevent Tastes and Odors Due to Microscopic Organisms, by W. W. Brush; discussion by S. T. Powell, F. E. Hale, P. Gear, Allen Hazen, W. F. Wilcox, E. G. Reynolds and the author.

Recent Practice in the Removal of Odors by Aeration, Filtration and Other Processes,[11] by N. J. Howard; discussion by W. C. Lawrence, Allen Hazen, F. E. Hale and the author.

Recent Developments in Chlorination, by W. J. Orchard.

After presentation of the above papers, the members present at the meeting signified their unqualified approval of extending future conventions through Friday, as had been done this year.

Editor Wolman then read a resolution prepared by W. W. Brush which provided that the Secretary be instructed to inform the American Committee on Electrolysis that the financial aid which the Association will furnish to the work of the Committee will be limited to the funds raised specifically for this purpose, and that no obligation will be assumed by the Association to furnish $2500 or

[11] See page 766 of this JOURNAL.

any part thereof annually for the next two years as requested by the Committee, and that the Association will continue to aid the committee as far as possible under the above limitations. This resolution was passed by the Executive Committee to be submitted to the Convention for approval. The resolution was adopted by the meeting.

The following appointments by the Executive Committee were announced also by Editor Wolman:

Secretary	J. M. Diven
Editor	Abel Wolman
Publication Committee	R. B. Morse, *Chairman* Malcolm Pirnie G. H. Fenkell H. E. Jordan Abel Wolman, *Editor*
Finance Committee	G. C. Andrews, *Chairman* J. W. Ackerman E. L. Nuebling
Membership Committee	T. A. Leisen, *Chairman* J. E. Gibson Wm. Young
Convention Committee	Harry T. Huy, *Chairman* E. E. Wall J. M. Diven

Afternoon session, May 19. Presiding officer, President-Elect Cramer.

The first paper presented was the Report of the Committee on Meter Schedules,[12] by I. S. Walker, in the absence of A. Hazen, chairman; discussion by W. S. Cramer, D. R. Gwinn, A. Hazen, E. T. Cranch, W. A. Megraw, J. C. Trautwine, H. P. Bohmann, N. M. R. Wilson and I. S. Walker.

On the motion from the floor, it was recommended to the Council on Standardization that the scope of the above Committee be extended to include the entire question of rate structure and rate making.

The following papers were then read:

Steel Pipe, by T. A. Leisen; discussion by G. W. Fuller, H. P. Bohmann and the author.

[12] JOURNAL, July, 1922, page 636.

Steel Pipe, by G. A. Elliott, presented by title.

Design, Construction and Operation of A Balancing Reservoir, by W. A. Megraw; discussion by J. C. Trautwine and S. M. Van Loan.

The discussion then reverted to steel pipe, with comments by S. M. Van Loan, D. A. Reed, T. A. Leisen and J. C. Trautwine.

The meetings were adjourned after a most sucessful week to be called to order again in 1923 in Detroit, Michigan. The attendance during the week was over eight hundred.

Chemical and Bacteriological Section, afternoon session, May 18. Presiding officer, Allen Hazen.

The order of presentation of papers was as follows:

Water Softening by Base Exchange, by E. Bartow and G. C. Baker; discussion by A. Hazen, J. H. Gregory, F. E. Hale, J. J. Hinman, C. A. Jennings, M. F. Corin, A. M. Buswell, S. T. Powell, C. P. Hoover, and E. Bartow.

Report of Committee on Standards Methods of Water Analysis, read by J. J. Hinman, Jr., chairman; discussion by A. Hazen, A. M. Buswell, T. Saville, M. Pirnie, H. E. Jordan, L. I. Birdsall, and J. J. Hinman, The report was accepted.

Report of Committee on Colloidal Chemistry in Relation to Water Purification, read by R. S. Weston, chairman; discussion by G. F. Catlett, G. D. Norcom, W. M. Clark, J. W. Ellms, C. A. Jennings, A. M. Buswell, J. R. Baylis and R. S. Weston.

The Microbiology of Activated Sludge, by A. M. Buswell.

Further discussion took place on problems in hydrogen ion concentration by A. M. Buswell, N. J. Howard, W. M. Clark, A. V. Graf, F. E. Hale, G. F. Catlett and A. Wolman.

Afternoon session, May 19. Presiding officer, Allen Hazen.

The following officers were presented by the nominating committee and were elected unanimously: Chairman, H. E. Jordan; Vice-chairman, A. L. Fales; Secretary, J. J. Hinman, Jr.; Executive Committee, L. H. Enslow, A. M. Buswell and MacHarvey McCrady.

The papers included in the symposium on "Tastes and Odors" were the following:

The Effect of Wastes from Oil Refineries Upon the Operation of the Filter Plant at East Chicago, by H. E. Jordan; discussion by P. Boynton, S. deM. Gage, P. Hansen, W. Donaldson, J. W. Ellms, L. L. Jenne and the author.

Some Observation on Chlorine Tastes and Odors, by W. Donaldson.

Taste and Odor in Baltimore Water Supply, by J. W. Armstrong, presented by J. R. Baylis.

Taste and Odor in New York City's Water Supplies, by F. E. Hale.

Experiences in Philadelphia, by L. L. Jenne.

Tastes and Odors in Public Water Supplies from Decomposing Organic Matter, by F. H. Waring.

Tastes and Odors Through Sewage Pollution, by G. E. Willcomb.

The presiding officer then called for brief recitals of experience from the following members, W. S. Curtis, C. P. Hoover, J. W. Ellms, G. W. Fuller, C. G. Hyde and I. S. Walker.

The last paper was read by N. J. Howard on Chlorination Prior to Filtration with Special Reference to Efficiency, Economy and Removal of Excess Chlorine.[13]

A paper on Reactions of Culture Media by G. C. Bunker and H. Schuber was presented in abstract by Editor Wolman.

The meeting then adjourned. The attendance at the sessions varied from 150 to 200.

CANADIAN SECTION

The meeting opened at 1:30 p.m. on Friday, May 12, 1922 at the Kerby Hotel, Brantford, Ontario. Chairman R. C. Harris, presiding, expressed the satisfaction of the officials of the Section at such a splendid attendance, complimenting those whose efforts were responsible for the success of the meeting and the representative exhibit of manufacturers' water works supplies. He believed the membership of the Canadian Section should be increased and that its usefulness would be felt more and more, as the smaller towns became affiliated.

After the minutes of the previous meeting and the Treasurer's report were read, and adopted, there was considerable discussion regarding means of increasing the funds of the Section. A resolution was adopted instructing the Secretary to communicate with Secretary Diven to determine if an additional grant would be possible.

The ballot taken for the election of officers resulted as follows: Chairman, R. L. Dobbin, Peterborough; Vice-chairman, F. A. Dallyn, Toronto; Secretary-Treasurer, C. D. Brown, Walkerville; Trustees, 1922–25, R. H. Starr, Orillia; 1922–24, J. J. Salmond, Toronto; and 1922–23, Norman Wilson, Brantford.

[13] JOURNAL, July 1922, page 606.

The paper by F. A. Dallyn, "What the Provincial Board of Health is Doing to Protect the Various Water Works Throughout the Province from Sewage Contamination" was followed by much discussion.

The next paper, "Filter Plant Construction," illustrated with lantern slides was read by R. L. Dobbin. The speaker answered many questions relative to conditions and costs at Peterborough. Theodore A. Leisen of Detroit here addressed the meeting.

The place of holding the next annual meeting was discussed and Windsor, as the centre of the Border Cities, was selected by a unanimous vote. In the evening, the delegates and guests proceeded to the Brantford Golf and Country Club, where they were entertained at a banquet as the guests of the Brantford Water Commission. Later the delegates attended a concert of H. M. Scots Guards Band in the Brantford Armories.

The second day's meeting opened at 9 o'clock a.m. Saturday, May 13, 1922, with a paper on "Standardization of Hose Threads," by Norman R. Wilson.

This paper brought out considerable discussion and resolutions were adopted instructing the Secretary to refer the question to the Canadian Engineering Standard Association, and also to the Standards Committee of the American Water Works Association.

Theodore A. Leisen addressed the meeting on membership.

Prof. Peter Gillespie, of Toronto University, read his paper entitled, "The Manufacture of deLavaud Cast Iron Pope," illustrated with lantern slides and moving pictures.

Wm. Gore read a paper on "Treatment of Impure Hard Water," following the discussion of which a moving picture of trenching and backfilling machinery in operation was shown.

Resolutions were adopted thanking the Chamber of Commerce and the Brantford Water Commission for all they had done to assist the Section in carrying through its most sucessful meeting.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Water Softening Proposed at Minneapolis. L. I. Birdsall. Mun. Cty. Engr., **62**: 108–9, 1922. The Mississippi River water varies in total hardness from 220 to 100 parts per million, with an average of 172 p.p.m. of which 162 p.p.m. are alkalinity and 7.1 p.p.m. sulphate. The use of lime is being tried in an experimental plant.—*Langdon Pearse.* (*Courtesy Chem. Abstr.*)

Symposium on the Centralized Softening of a Public Water Supply. Mun. Cty. Engr., 62: 103–8, 1922. Various experts state the feasibility of softening a hard water and urge the economical and aesthetic desirability. Limits of hardness are discussed. The use of lime and soda are generally recommended.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Terre Haute Water Co. Uses Malleable Street Vault Covers to Stand Shocks of Heavy Truck Wheels. D. R. Gwinn. Mun. Cty. Engr., 62: 66–8 1922. Ordinary grey iron covers, proven defective under modern truck loads, are replaced by malleable iron covers and frames, with 18-inch diameter opening weighing 215 pounds. These have not broken on account of the higher ultimate tensile strength of the material (45,000 pounds per square inch.).—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Underground vs. Surface Water Supplies with Special Reference to Wauseon, Ohio. W. J. Sherman. Mun. Cty. Engr., **62**: 63–6, 1922. After serious failure of a well supply in water bearing gravel, a development was made of a surface supply with a drainage area of 4.4 square miles by pumping, with a 60,000,000 gallon earth reservoir. The water is aerated, stored, and filtered. The filter plant has a capacity of 750,000 gallons per 24 hour. Natural gas is used for over half the fuel. *Langdon Pearse.* (*Courtesy Chem. Abst.*)

Cap de la Madeleine Water and Sewer Systems. Romeo Morrisette. Can. Engr., **42**: 403–6, 1922. Describes the remodelling of the systems in a town of 6730 people. Detailed costs are given. The cost of laying cast iron pipe was, for 4 inch, $0.103 and, for 6 inch, $0.148 per linear foot. Trenches cost $0.74 per linear foot.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Experience in Centralized Water Softening in McKeesport, Pa., Muskogee, Okla. and Georgetown, Ky. Alexander Potter. Mun. Cty. Engr., **62**:

147–8, 1922. Municipal water softening is entirely practicable. The essentials are complete solution of the chemicals, thorough agitation, and adequate sedimentation.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Discussion of the Centralized Softening of a Public Water Supply. George A. Johnson. Mun. Cty. Engr., 62: 145–7, 1922. Points out feasibility of central softening plants, on lime and soda process or permutation bases, and urges more general use.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Methods and Costs of Building 10 Million Gallon Reinforced Concrete Reservoir for the Indianapolis Water Co. W. C. Mabee. Indiana San. & W. S. Assn. 1922. Mun. Cty. Engr., 62: 141–5, 1922. Structure is designed to store 10 feet 3 inches of water, and to carry an upward pressure of 10 feet of water on the bottom. Groined arch construction (minimum thickness 9 inches) was used for the bottom with a 9 inch flat slab roof, covered with 27 inches of fill. The columns are 24 inches square, 18 feet on centers. The reservoir is 254 feet wide by 542 feet long. The cost was per million gallons water stored, $19,150. Unit costs were excavation $0.56 per cubic yard, concrete $13.05 per cubic yard, placing reinforcing $15 per ton. Wooden forms were used.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Recognition of an Undepreciated Rate Base in some Recent Decisions. W. H Blood, Jr. Stone & Webster Jour., Dec., 1921. Eng. & Cont. 57: 232 1922. Cites and abstracts a number of cases where an undepreciated base was recognized by the courts in determining rates for utilities.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Engineers Plans for State Boards of Health. Pub. Wks., 52: 237–8, 286–7 341–2, 1922. The practice in various states is described on submission of plans for approval in water or sewage work.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Effect of Gas Plant Wastes on Taste and Odor of Water. C. M. Baker. Proc. Am. Soc.C. E., Dec. 1921, Jan. 1922. Eng. & Cont., 57: 132–3, 1922. Baker describes Milwaukee experience in 1918, where coal tar derivatives were objectionable. Phenol was detected by taste in dilution of 1 to 500,000,000. Closing of a phenol plant temporarily remedied condition. Later tastes were traced to intermittent discharge of gas wastes. By making discharge continuous, conditions were remedied.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Filter Plant Control and Operation. Pub. Wks., 52: 343–5, 1922. Representatives of 46 water purification plants in Ohio give detailed notes on filter plant control and operation, covering collection of samples, standard methods of analysis and operation, including sedimentation, coagulation, filtration and disinfection.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Birmingham's Water Works System. N. M. Berberick and W. A. Hardenbergh. Pub. Wks., 52: 331–4, 1922. The privately owned system has

grown from 4500 consumers in 1900 to 29,500 in 1921, using nearly 20,000,000 gallons per 24 hours. Water is taken from two sources. A storage dam impounds a reserve supply. The company owns its coal mine. The water is filtered, new equipment being added to old tub filters. 0.2 p.p.m. liq. Cl. are added to filtered water. The average turbidity in 1921 was 300 in the raw water, reduced in receiving basin (125,000,000 gallons capacity) to 75 and in settling basin (30,000,000 gallons capacity) to 25. The filters remove all the bacteria except 5 per cubic centimeter on an average.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Repairing Chicago Water Works Crib. Pub. Wks., 52: 335–6, 1922. The four-mile crib is a steel shell concrete pier 114 feet diameter in water 38 feet deep. The protecting crib was repaired by driving steel sheet piling and filling inside with bags of concrete to seal the cofferdam, then concreting to a height of 9½ feet above water.—*Langdon Pearse.*

Decatur's New Water Works Dam. E. E. Pierson. Pub. Wks., 52: 336–7, 1922. Describes a $2,000,000 project, including a dam (1100 feet earth, 550 feet concrete spillway), changing bridges and approaches and acquiring the flowage rights, on 4200 acres. A water supply association was formed to acquire the flowage rights, the city paying the interest and sinking fund by an increase in the water rates, and acquiring ownership in 20 years.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Decreasing Typhoid Mortality. Pub. Wks., 52: 340–1, 1922. U. S. Pub. Health Service figures indicate remarkable reduction in typhoid from 1916 to 1920.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

How to Determine Need of Water Extensions. George R. Popp, Jr. Fire and Water Eng., 71: 605, April 12, 1922. Investigation of water loss through waste in order to obtain information for the intelligent expansion of distribution systems. Paper read at convention of Indiana San. & Wat. Sup. Assoc. *Geo. C. Bunker.*

Form Temporary Company to Overcome City Debt Limit. Phil Carlin. Fire and Water Eng., 71: 608, April 12, 1922. An unusual experiment in water works financing, namely, the formation of a temporary holding company composed of citizens of Sioux City, Ia., in order to overcome the difficulty which confronted the city of extending the water system without the issuance of bonds, which the city was unable to do at the time, owing to statute limitations. As soon as the water works became a self-supporting investment the citizens turned the utility over to the city. The water department now has 10,600 services and is 100 per cent metered. No tax levies for water purposes have been made since 1908. Receipts have grown from $18,370.09 in 1891 to 227,804.63 in 1919.—*Geo. C. Bunker.*

Water Supply of the Delft District. T. G. J. Francken. Water en Gas, 36–9, Feb. 3, 1922. (cf. Water & Water Eng. London, 24: 149, April 20, 1922.)

Steps were recently taken to improve the supply. A pumping station was installed and a reinforced concrete reservoir constructed with separate annular compartments which favor good circulation and allow cleaning to be carried on without interfering with the supply. Part of the water will be taken from the Rotterdam supply, part from shallow wells in the dunes, and later on the deep water supply will be tapped. Three existing settling basins of 1600 m. total capacity were reconstructed as rough filters in order to enlarge the capacity of the two slow sand filters with a total surface area of 600 m. A cast iron pipe line, 375 mm. diameter, with lead joints was run from Rotterdam. At the final test the line lost 50 liters per hour at pressure of 8 atmospheres.—*Geo. C. Bunker.*

The Provincial Supply of Drinking Water for North Holland. B. F. van Nievelt. Water en Gas, 19–21, Jan. 20, 1922. (cf. Water & Water Eng. London, **24**: 149, April 20, 1922.) Discussion of the tariff regulations made uniform throughout the Province. As the undertaking will have in a few years 100,000 consumers, the capital and other charges for meters, if installed generally, would amount to a 40 per cent addition to the price of water, so the tariff was based on the number of rooms or floor space, with meters on industrial services, as being the most economical. Cost of collection of water rates is considerably reduced by payments through the post offices.—*Geo. C. Bunker.*

The Corrosion of Boilers and the Treatment of Boiler Feed Water. A. Winstanley. Water & Water Eng. (London), **24**: 47, February 20, 1922. 2400 words. The author is of the opinion that many of the waters now treated by the lime soda process could be more efficiently treated in other ways and barium hydrate is mentioned as a substitute. A low degree of hardness does not always indicate that the water will be good for use in boilers. Two discussions of the above paper are given in the March 20 issue of the same Journal, page 90. R. H. Froude opposes the use of barium hydrate in place of lime and soda, pointing out the many disadvantages of the former as well as its high cost. The latter agrees that a low degree of hardness does not always indicate that the water will be good for boilers; the nature of the salts causing the hardness is the guide.—*Geo. C. Bunker.*

Portable Kit Measures Corrosiveness of Water. Power, **55**: 644, April 25, 1922. A description of a simple but accurate method of measuring the amount of dissolved oxygen in a sample of water in connection with the operation of a deaerating apparatus. Written for engineers or operators who have no knowledge of chemistry. Illustrated.—*Geo. C. Bunker.*

What to Know When Selecting Stoker Equipment. J. G. Worker. Power, **55**: 647, April 25, 1922. The combustion characteristics of the principal coals in the U. S. and the types of stokers best suited to burn these coals are listed.—*Geo. C. Bunker.*

The Wheatstone Bridge and How It Operates. C. A. Armstrong. Power **55**: 655, April 25, 1922. A simple illustrated explanation is given of the Wheat-

stone bridge and then it is shown how this device is applied to determining the condition of boiler-feed water.—*Geo. C. Bunker.*

Purification of Water with Lime. (Waterreiniging met behulp van kalk). Jan. Smit. Meded. Burgerlijk. Geneesk. Dienst in Nederl.-Indie. 1921. Pt. 2. 112–189. Abstract; Sanitation Supplement-Trop. Diseases Bull. (London), 1; 34, March 30, 1922. Houston's method, depending upon a long time contact of the water with a small excess of lime, does not give entirely satisfactory results in the tropics. On adding lime to a turbid river water of Java, so as to give an alkalinity to phenolphthalein equivalent to 2.5 cc. of N/1 acid per liter, and filtering it immediately after through sand, a crystal-clear filtrate containing few bacteria will be obtained. It is claimed that the above alkalinity will kill typhoid and cholera germs and B. coli in a short time. Lime is therefore considered superior to alum as a clarifier.—*Geo. C. Bunker.*

Researches on the Spontaneous Purification of Water Kept in Large Reservoirs in Untempered Sunlight. (Onderzoekingen over de zelfreinigging van in groote reservoirs onder toetreding van het volle zonlicht bewaard water). P. C. Flu. Geneesk. Tijdschr. v. Nederl.-Indie. **61:** 3, 294, 1921. Abstract; Sanitation Supplement-Tropical Diseases Bull. (London), **1:** 35, March 30, 1922. The author repeated under tropical conditions the experiments of Houston (Thames river water) on the improvement of physical, chemical and bacteriological properties of water from River Tijiliwoeng (Batavia) kept in open basins of 35 liters or a cemented reservoir of 80 cu. m. Cholera, dysentery and typhoid germs disappeared within one week, the first two quicker than the last. In a tropical lowland climate, surface water may be rendered practically harmless by storing it in large open reservoirs for 8 days. Storage may be strongly recommended in cases where the source of a water supply is exposed to gross pollution and a strict bacteriological control of the filtered water is impossible.—*Geo. C. Bunker.*

The Valuation of Waterworks. Water & Water Eng. (London), **24:** 117 April 20, 1922. A review of a paper read by George Baxter, of Dundee, at the annual meeting of the Institution of water Engineers on The "Valuation and Rating of Waterworks." Mr. Baxter referred in some detail to the inequalities in the distribution of the burden as between parishes where actual supply takes place and those which merely contain the pipes and reservoirs of the undertaking, but his main purpose was to show that the valuation of waterworks on the revenue principle, which permits of disturbing fluctuations and is dependent solely on the money required annually to meet the capital charges of the undertaking, is inequitable.—*Geo. C. Bunker.*

Prevention of Corrosion of Metals by Water in a Closed System. PERRY WEST. Jour. Ind. & Eng. Chem., **14:** 7, July 1922. The theory of corrosion by an aggressive water is described and illustrated by sketches, showing the progressive stages of corrosion and its electrochemical nature involving hydrolysis and ionization. At 180° F. corrosion is about ten times as rapid as at 50° and at 210° it is again about ten times rapid as at 180°. Annual loss in do-

mestic hot water service due to corrosion is estimated at $50,000,000. Evidence proves the rate of corrosion to be directly proportional to the concentration of dissolved oxygen in various waters. Curves are presented showing the solubility of oxygen in water at varying temperatures and under different pressures. The high limit of dissolved oxygen for certain cases is 0.75 cc. per liter, but to prevent serious corrosion in the modern high-pressure steam plant, such must be maintained at 0.2 cc. or less. Two types of commercial deactivators designed for hot water systems in apartment houses, large building and boiler-plants are described and illustrated. It is claimed that they remove practically all dissolved gases, including oxygen, by an initial physical process followed by a chemical finishing process. The equipment is claimed to have proven an economic success.—*L. H. Enslow.*

Sewage, Applicability of the Process of Purification of, by Activated Sludge to the Separative System. L. Cavel. Comptes rend., **174**: 578–580, 1922. J. Soc. Chem. Ind., **41**: 229a, 1922. Laboratory experiments conducted on a strong sewage, obtained from a town where the separative system is adopted and thus the sewage is not diluted by rain water, show that the activated sludge process may quite well be applied to such material. In the laboratory trials the alkalinity, the ammonia, and the sulphides disappeared completely, the oxidisability was lowered by 72.8 per cent, the number of bacteria by 92.4 per cent, and the organic nitrogen by 76 per cent.—*W. G.* (*Courtesy A. M. Buswell*)

Bacillus coli, Biology of. Endo's reaction. O. Fernandez and T. Garmendia. Anal. Fis. Quim., **19**: 313–319, 1922. J. Soc. Chem. Ind. **41**: 229a, 1922. The red color produced by B. coli in Endo's medium (bouillon, with agar containing lactose, fuchsin, and sodium sulphite) is probably produced not by acetaldehyde but by lower acids of the fatty series. The production of acetaldehyde by the agency of B. coli was studied using different modifications of Endo's medium. (Cf. J. C. S. April.).—*G. W. R.* (*Courtesy A. M. Buswell*)

The Treatment of Swimming Pool Water with Ultraviolet Rays. W. F. Walker. Amer. Jour. Pub. Health, **12**: 320, 1921. Illustrations show desirable features in swimming pool design. Relative rate of purification for eight and twenty four hour operating day periods are shown by charts. The author concludes that the high turn-over rate and uniform distribution are essential, that bacteriological standards should be used, that a high flow of fresh water gives satisfactory results but is expensive, that re-circulation with filtration and sterilization by ultraviolet rays gives satisfactory counts in the pool.—*A. M. Buswell.*

Industrial Wastes in Relation to Water Supplies. Wellington Donaldson. Amer. Jour. Pub. Health, **12**: 420–2, May, 1922. A continuation of the discussion of the subject as set forth in a previous article (this journal, 11, 193) In this paper the author calls attention especially to petroleum wastes, wastes from oil well operation and various other industries. He calls especial atten-

tion to the importance of the mineral analysis in detecting pollution from certain manufacturies such as zinc smelters, etc.—*A. M. Buswell*

Lead, Determination of Minute Amounts of, in Water, with Notes on Certain Causes of Error. D. Avery, A. J. Hemingway, V. G. Anderson, and T. A. Read, Proc. Austral. Inst. Min. Met., 173–199, 1921. Jour. Soc. Chem. Industry, **41**: 154 a., Feb. 28, 1922. The sample is filtered and the lead determined in the sediment and clear liquid separately. 2.5 to 5 l. of the latter is evaporated to 250 cc., neutralised, and treated with an excess of 2 cc. of hydrochloric acid; the solution is again filtered and the filtrate saturated cold with hydrogen sulphide. After standing overnight, the solution is filtered, the precipitate washed with hydrogen sulphide water, and dissolved in nitric acid. The solution is evaporated with 1 cc. of sulphuric acid until it fumes, 20 cc. of water and 10 cc. of absolute alcohol are added, and the lead sulphate filtered off next day. It is dissolved in ammonium acetate and the solution, in a Nessler tube, treated with 1 cc. of 10 per cent potassium cyanide solution, 1 cc. of ammonia, and six drops of freshly prepared ammonium sulphide solution. The color is compared with that obtained by adding the same amounts of reagents to a standard lead solution (1 cc. 0.00001 g.Pb). The sediment is evaporated to dryness with hydrochloric acid, the residue treated with 2 cc. of the same acid and 250 cc. of water and the filtered liquid treated as described above. Waters containing organic matter, e.g. urine, are evaporated with nitric acid to dryness, the residue is heated to 450°–500°C., for 20 minutes, and the cold mass extracted with hydrochloric acid. The filtered solution is then treated as described above. All the reagents used must be redistilled from glass apparatus free from lead, the filter papers must be washed free of lead with hot hydrochloric acid hot ammonium acetate and hot water succssively, and a volume of distilled water equal to that of the sample must be put through the whole process as a blank. (Cf. J. C. S. Mar.)—*A. R. P.* (*Courtesy A. M. Buswell*).

How Maps Speed Up Valve Closing. Wm. W. Brush. Fire and Water Eng., **71**: 19, 779, May 10, 1922. To facilitate the location and closing of valves in a waterworks distribution system, a system of maps showing mains, valves, sizes and number of turns is described.—*A. W. Blohm.*

What Do You Know About Water Works Finance? William H. Lawrence. Fire and Water Eng., **71**: 19, 781, May 10, 1922. Water rates depend on the financial management of a water works. A method of financing is explained, which includes a sinking fund for liquidating the bonded debt and a depreciation fund to provide for renewals.—*A. W. Blohm.*

Some Practical Experiences with Meters. J. W. Hockaday. Fire and Water Eng., **71**: 19, 785, May 10, 1922. Experiences of the Water Department of Cleburne, (Texas), in the placing and inspection of water meters.—*A. W. Blohm.*

Efficient System for Filing Water Service Records. Dow R. Gwinn. Fire and Water Eng., **71**: 19, 787, May 10, 1922. Water Works Company of Terre

Haute (Ind.), uses envelopes of heavy Manila, for filing purposes. An envelope is kept for each service, in which all necessary data are filed. A card index is also used so that all of the information is instantly available.—*A. W. Blohm.*

Good Publicity Will Keep Consumer Happy. Fred Shepperd. Fire and Water Eng., **71**: 19, 789, May 10, 1922. Value of private plants keeping in touch with patrons, by means of advertising, is brought out.—*A. W. Blohm.*

Keeping Tab On What You Have Underground. Robert F. Johnson. Fire and Water Eng., **71**: 19, 790, May 10, 1922. Saginaw, (Mich.) keeps records of watermains, service connections, fire hydrants, etc. The payment of water for public use, and the collecting of water bills is discussed.—*A. W. Blohm.*

Find Out Where All Your Water Goes. A. S. Holway, Fire and Water Eng., **71**: 19, 791, May 10, 1922. Oklahoma City (Okla.), by a careful water waste survey, located and repaired leaks in mains and fire hydrants, and replaced old or dead meters. This survey with careful inspection is saving daily 2,800,000 gallons of water, or 41 per cent of the present total pumpage.—*A. W. Blohm.*

A Filtration System With Unique Features. George A. Johnson. Fire and water Eng., **71**: 19, 793, May 10, 1922. Article describes in detail watershed conditions, and design of the water filtration plant, under construction, at Cambridge, Mass.—*A. W. Blohm.*

What A Water Works Man Has To Contend With. Fred Shepperd. Fire and Water Eng., **71**: 19, 795, May 10, 1922. Several incidents are cited of various means employed by the water thief, to escape payment for water used.—*A. W. Blohm.*

Efficiency Test of Water Works Pumping Machinery. L. M. Gazin. Fire and Water Eng., **71**: 19, 799, May 10, 1922. Details of tests, for speed and capacity, of two pumping units and turbines at Fort Smith, Ark.—*A. W. Blohm.*

Clarksburg, W. Va., Water Supply. Scotland G. Highland. A neat booklet with nine good illustrations of the 9 m.g.d. plant. Leaky fixtures and the remedy are well and practically treated. Interesting extraneous matter included.—*Frank Hannan.*

Water Meters and Water Loss in Indiana. Anon. Eng. News-Rec., **88**: 612, 1922. At East Chicago, Ind., meters reduced the consumption from 200 gallons per capita in 1920 to 70 gallons in December, 1921 when only 12 per cent was unaccounted for. At Gary 83 per cent of the water pumped to their 50 per cent metered system was accounted for. Losses at North Manchester were only 6.77 per cent and at Lexington, Ky., 16.5 per cent. Of the $50,000

being spent by the Frankfort Water Company on new work, $33,000 was for meters.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Operating Data for Three Filters Using Lake Michigan Water. S. A. GREELEY AND H. E. JORDAN. Eng. News-Rec., **88**: 578–9, 1922. Data compiled for filter plants at East Chicago, Whiting, and Evanston. The plants have a rated capacity of 8, 4, and 12 m.g.d. respectively. Comparative data indicated that the cost of coagulants in the East Chicago and Whiting plants was more than double that at Evanston. This difference is no doubt due to the character of the raw water.—*Frank Bachman.* (*Courtesy Chem. Abst.*)

Typhoid Fever From Water Held Compensable. Anon. Eng. News-Rec., **88**: 617, 1922. Under the Workmen's Compensation Act of Indiana according to a decision of the Appellate Court, typhoid fever contracted from impure water is held to be an "injury" by accident arising out of and in the course of the employment.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Estimated and Average Daily Water Consumption in St. Louis. EDWARD E. WALL. Eng. News-Rec., **88**: 619, 1922. The figures show that the annual daily average will be exceeded by 125 per cent for the maximum month in any year; by 135 per cent for the maximum week; and by 150 per cent on the maximum day.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Waterproofing a Leaky Reservoir at Nashville, Tenn. J. N. CHESTER. Eng. News-Rec., **88**: 310–2, 1922. The leakage was remedied by a lining composed of 2 layers of gunite with an asphaltic burlap membrane between them.—*Frank Bachmann.*

Importance of Railway Water Supply. Committee Report. Amer. Railway Eng. Assn., 1922. Eng. News-Rec., **88**: 640, 1922. Railroad water consumption aggregates 900 billion gallons at 14,000 stations involving $100,000,000 for operation and maintenance per year. This expense is considered small as compared to operation and repair of locomotives due to poor water supplies.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Legislation and Procedure for Enforcing Correction of Stream Pollution and Improvement of Water Supplies. Administrative Bulletin No. 133, Ohio State Department of Health, 1921. A compilation of the laws providing for correction of pollution of streams by sewage and other wastes from municipalities, institutions, industrial establishments and other sources, and for the improvement of impure and unsafe public water supplies of municipalities and public institutions.—*E. S. Chase.*

Report of the Department of Food, Drugs, Water and Sewage, Monthly Bulletin, Indiana State Board of Health, 24: 12, 136, December, 1921. Two examples of sanitary hazards to water supply are given. At one filter plant the single low service pump to the filters was broken and raw water was pumped directly to the town. At another water works the supply of chlorine for sterilization

had become exhausted and unsterilized water had been delivered to the city resulting in an outbreak of intestinal trouble.—*E. S. Chase.*

The Romance of Water Storage. George A. Johnson. North Carolina State Board of Health. **36**: 12. A paper setting forth in a popular way Johnson's well-known views on storage as an inadequate method for protecting the sanitary quality of public water supplies.—*E. S. Chase.*

Development of Water Supply in the Metropolitan District. Morris R. Shepperd. Public Health News, N. J. State Department of Health; **7**:4–5, 83, March–April, 1922. Points out the need of planning for the future water supply needs of the New York Metropolitan area, and particularly that part located in northern New Jersey. The population of the N. J. territory is increasing at approximately 4 per cent per year and water consumption somewhat faster. It may be estimated that in the next 25 years a supply of 500,000,000 gallons daily will be required and in 50 years, 1,000,000,000 gallons for the New Jersey territory alone. He concludes that inasmuch as there will exist the need of reciprocity between neighboring states in water supply matters, a commission be established representing the States of Pennsylvania, New Jersey, New York and Connecticut.—*E. S. Chase.*

1921 Vital Statistics Review for New York State. Monthly Bull. N. Y. State Dept. Health. **2**: 12, Feb. 1922. Of interest to the water works engineer is the marked decline in typhoid fever shown by a diagram in this bulletin. In N. Y. the typhoid fever death rate, which was approximately 32 per 100,000 has declined to 3.6 in 1921.—*E. S. Chase.*

Semi-annual Report Div. Eng. and Sanit., July–December, 1921. H. F. Ferguson. Illinois Health News, **8**: 3, 64, March 1922. A review of the activities of this division which include consideration of proposed water supply projects, examination of existing supply, and inspection of purification plants and co-operation with U. S. P. H. S. in supervision of water supply for common carriers. The review tabulates the investigations made regarding water supplies between July 1, 1918 and June 30, 1920. A program for further work of the division is also outlined.—*E. S. Chase.*

Water Treatment from an Investment Standpoint. L. F. Wilson. Railway Review, 69: 602–19, 1921. Consideration is given to the varying quality of railroad water supply and attention is called to the economy of internal treatment where expense of treating plant installation is not warranted.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

The Interior Treatment of Boiler Waters. C. R. Knowles. Railway Age, **71**: 935–20, 1921. It is estimated that 50 per cent of the boiler water used on Amer. railroads is of such quality that treatment would show economy in locomotive operation and of this amount only 6 per cent is being treated by exterior method. Construction of treating plants for the remaining 94 per cent will take years, and interior treatment is recommended in the meantime. *R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Use of Boiler Compounds. L. F. WILSON. Railway Age, 71: 1077–23, 1921. Comments on Knowles Article. Interior treatment is recommended.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Interior Boiler Treatment as an Alternative. R. C. BARDWELL. Railway Age, 71: 1184–25, 1921. Comments on Knowles article. Careful check of water quality is recommended.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Boiler Compound and Anti-Foaming Compounds. W. H. Hobbs. Railway Age, 71: 1132–24, 1921. Comment on Knowles article. Difference between anti-scale and anti-foam compounds is emphasized.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

A Difference of Opinion on Water Treatment. W. H. GREEN. Railway Age, 72: 313–5, 1922. Comments on Knowles articles. Excessive agitation is harmful. Filtration is beneficial to remove the foaming tendencies caused by suspended matter.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Improvement and Control of Boiler Waters. W. M. BARR. Railway Age, 72: 364–6, 1922. Comments on Knowles Article. U. P. R. R. uses 75 per cent of all anti-foaming compound on district which has no softening plants. Careful check of water quality is recommended.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

An Advocate of Soda Ash. R. W. CHORLEY. Railway Age, 72: 412–7, 1922. Comments on Knowles article. Where incrusting solids are not high, treatment of water in wayside tanks is recommended.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

The Boiler Compound. D. K. FRENCH. Railway Age, 72: 907–15, 1922. Comments on Knowles article. Quotations from several articles are given favoring use of boiler compounds.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Treated Water Improves Locomotive Performance. W. A. POWNALL. Railway Age, 72: 794–12, 1922. Comments on Knowles article and gives full review of soda ash treatment on Wabash Ry. Tests show that with excess soda ash treatment and proper blowing off results will, (1) Keep heating surfaces comparatively free from scale, (2) Cause the scale forming solids to be deposited as soft sludge, (3) Practically eliminate engine failures due to leaky flues, fireboxes, etc. (4) Reduce staybolt breakage and fire box renewals. (5) Decrease cost of boiler repairs (6) Increase mileage between washouts.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

The Interior Treatment of Boiler Waters—A Criticism. C. H. KOYL. Ry. Age, 71: 1241–26, 1921. Comment on article by Knowles. Foaming is caused by sludge and suspended matter. Instance is cited where a water containing 1000 gr. per gal. initial Na salt conc. is used successfully. External treatment is advocated where water contains over 12 gr. per gal. incrustants.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Study of Progress of Regulations of Federal or State Health Authorities Pertaining to Drinking Water Supplies. Comm. Report Amer. Ry. Eng. Assoc. Bul., **242**: 487, 1921. Ry. Age, **72**: 689–10, 1922. Review of recent regulations by Public Health Dept. relative to railway drinking water supplies.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Effect of Local Deposits on Pollution of Surface and Shallow Well Water Supplies. Com. Report. Amer. Ry. Eng. Assoc. Bul., **243**: 690 1921. Ry. Age, **72**: 689–10c, 1922. Typical instances of pollution are given.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Study and Report on Pitting and Corrosion of Boiler Tubes and Sheets, Character of Metal, Methods of Manufactures, Construction of Boilers, and Quality of Water Considered. Com. Report. Amer. Ry. Eng. Assoc. Bul., 243: 493, 1921. Ry. Age, **72**: 689–10c, 1922. A preliminary report. Survey of field indicates electrolytic actions as chief cause and investigation will be made further with this in view. Results of questionaire and photos showing typical conditions are given.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Study and Report on Specifications for Various Chemicals Used in Water Treatment. Com. Report. Amer. Ry. Eng. Bul., **243**: 498, 1921. Ry. Age, **72**: 689–10c, 1922. Specifications for soda ash, hydrated lime, quicklime, sulphate of alumina, and sulphate of iron were adopted.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Report on Centrifugal Pumps for Railway Water Service. Com. Report. Amer. Ry. Eng. Assoc. Bul. **243**: 508, 1921. Ry. Age, **72**: 689–10c, 1922. A full discussion of centrifugal pumps adaptable to railway service is given.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Standards. Com. Report. Amer. Ry. Eng. Assoc. Bul., **243**: 511, 1921. Ry. Age, **72**: 689–10c, 1922. Amer. Wat. Wks. Assoc. Spec. for C. I. pipe, and hydrants and valves were adopted as standard for railway service.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

University Work of Interest to Railway Water Supply. Com. Report Amer. Ry. Eng. Assoc. Bul., **243**: 527, 1921. Ry. Age, **72**: 689–10c, 1922. Investigations recently completed or underway at Purdue U., U. of Iowa, U. of Montana, U. of Manitoba, and Sheffield Scient. School were mentioned.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Water Analysis for the Non-Technical Man. Cass Kennicott. Railway Age, **72**: 1168–20, 1922. Recommendation is made for reporting results in lbs. per 1000 gal. which can be visualized by average operating official.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Missouri Pacific Continues to Show Large Savings from Water Treatment. Anon. Railway Age. 72. 1188–20, 1922. Mo. Pac. R.R. treated

1,781,560,000 gal. in 1921 removing 4,916,247 lbs. scaling solids at a total expense of $170,575. They had 77 treating plants which cost $309,611 and 34.6 per cent of water used was softened. Coal saved was 62,000 tons.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Indianapolis' Ten Million-Gallon Covered Reservoir. W. C. Mabee. Eng. News-Record, **88**: 739–40, 1922. This reservoir was built in 120 days and cost $223,500. High ground water limited the depth. It is 254 by 542 feet in plan and 10 feet 8½ inches deep. Method of construction and equipment used are detailed.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

New Jersey Tax Finances State Board. Anon. Eng. News-Record, **88**: 702, 1922. The Department of Conservation and Development levied $23,262 against 27 water-supply systems for excess diversion of water during 1921. The 27 systems supply 1,801,500 people and the charge amounts to 1.3 cents per capita.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

Operation and Tuning up of the Cleveland Filters. J. W. Ellms. Eng. News-Record, **88**: 776-9, 1922. Major changes consisted in reducing the number of baffles in the mixers, discarding certain of the lime-handling machinery, installing a dust filter for reducing the lime dust nuisance when unloading cars and substituting water ejectors for motor-driven pumps for feeding the various chemical solutions. The normal capacity of the plant is 150 m.g.d. but its actual capacity is 130 m.g.d. because it is impossible to operate the entire plant. Operating and analytical data are given.—*Frank Bachmann* (*Courtesy Chem. Abst.*).

CO_2, Odor and Iron at Virginia Beach, Va. Richard Messer, A. Wagner, & Linn H. Enslow. Eng. News-Record, **88**: 774–5, 1922. Raw water is taken from 31 driven wells in an old marsh area. The wells are 2 inches diameter and 20 feet deep. The water is highly colored and has a noticeable odor. Treatment consists of: aeration through nozzles; lime and chloride of lime treatment followed by sedimentation; filtration through sand; and storage in covered reservoir. The Cl aids in removal of color and odor. Main object of lime is complete removal of CO_2 and formation of "blanket" on filter. Installation has replaced cisterns as laundry supplies and bottle water for table use.—*Frank Bachmann* (*Courtesy Chem. Abst.*)

Mechanical Equipment for Detroit Water Main Extension. Anon. Eng. News-Record, **88**: 776–9, 1922. Approximately 100 miles of water mains ranging in size from 4 inches to 4 feet but mainly 6 to 8 inches, are laid per year. and because of this the city has organized a well equipped force. Machines are provided for trenching, handling pipe and back-filling and many special shop and field operations.—*Frank Bachmann.*

Central Repair Shop for Philadelphia Water-Works. John M. Broggini. Eng. News-Record, **88**: 772–3, 1922. Units heretofore scattered over the city have been brought together in a central shop.—*Frank Bachmann.*

Operation Control Panels for the Sacramento Filters. ANON. Eng. News-Record, **88**: 782–4, 1922. Unique features of control are: upright panels; valve-opening indicators of colored liquids in glass tubes; loss of head gages; rate of filtration. gages are air gages; and the wash-water rate is indicated directly from a Pitot tube in the wash line.—*Frank Bachmann* (*Courtesy Chem. Abst.*).

Largest Storage Reservoirs in the United States in Use in 1920. ALLEN HAZEN. Eng. News-Record, **88**: 799, 1922. A list of reservoirs with capacities compiled for the Committee on Water Supply of England Council.—*Frank Bachmann* (*Courtesy Chem. Abst.*).

Chester (England) Water Works: Past and Present. FREDERICK STORR AND C. WILFRED BENNETT. Water and Water Eng., **24**: 193, 1922. An historical account tracing the development from Roman times to date. Plant depends upon slow sand filters, but pressure filters of the Paterson type were contracted for in 1921.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Central Water Supplies for Settlements. Neuber. Zentralblatt der Bauverwaltung, 213, April 29, 1922. Water and Water Eng., **24**: 186, 1922. Compares costs of various plans for towns of less than 10,000 and finds that separate water works will in many cases be cheaper than individual wells and that cost of connecting to system of neighboring town may be no more economical on account of raising to high levels in the town.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Protection of Iron Against Rust. J. A. HEYMANN, Water en Gas, Mar. 31, 1922. Water and Water Eng., **24**: 227, 1922. Iron in contact with water gives off ferrous ions; if air be present, these change to ferric and $Fe(OH)_3$ is precipitated. Iron would not rust in moist air were temperature and pressure constant, otherwise moist air has same effect as water. Lengths of iron pipe were sand blasted and then painted with protective compositions. Then placed in glass cylinders containing gelatine 14 per cent potassium ferrocyanide 0.1 per cent, and 0.01 per cent phenol, in water, phenol for preventing bacterial growth. Appearance of iron demonstrated by blue color in the jelly. Siderosthen, bitumeni, and bitumen enamel were tested. Best protection by one coat and immediate immersion. No composition gave absolute protection. Action started in patches but went on over the entire surface.—*Jack J. Hinman, Jr.* (*Courtesy Chem Abst.*).

The Lozoya Water and Typhoid Fever. IOSE NICOLAU. Riv. de Obras Publicas, 2373; 2–9, 1922. Water and Water Eng., **24**: 186, 1922. Typhoid mortality in Madrid averages one-fifth of total. Has been attributed to Lozoya river water, from Isabella II canal. There are reasons to think protection of this source ample. Part of supply comes from the river Manzanares, but no reason to think differently collected than the Lozoya water. Discusses bacterial origin of paratyphoid and typhoid fevers.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Purification of Swimming Pools by Means of Chlorine. Bulletin d'Hygiene balnéaire et de Propreté, 9: 18, 1921. Bulletin Internat. Office d'Hygiene Publique, 14: 5, 582, May 1922. Review s the regulations of the State Boards of Health of California and Florida, and discusses the use of Wallace and Tiernan chlorinators in treating the water.—*Jack J. Hinman, Jr.*

Experiments on the Vitality of Cholera Vibrios and Typhoid Bacilli in Sea Water. P. C. Flu. Mededeelingen den Burgerlijken Geneeskundigen Dienst in Nederlandsch-Indië, 3: 317, 1921. Bulletin Internat. Office d'Hygiene Publique, 14: 5, 563, May, 1922. Experiments with sea water artificially contaminated. The cholera vibrios survived 4 or 5 days, as did the typhoid bacilli in one experiment. Similar results were obtained with the cholera vibrios and river water.—*Jack J. Hinman, Jr.*

Experiments on the Longevity of the V. Cholerae and B. Typhosus in Septic Tanks at Batavia. P. C. Flu. Mededeelingen Burgerlijken Geneeskundigen Dienst in Nederlandsch-Indië, 3: 289, 1922. Bulletin Internat. Office d'Hygiene Publique, 14: 5, 564, May, 1921. F. tried to recover the B. typhosus from the effluents of septic tanks using the method of precipitation by ferrous sulphate and sodium carbonate. No positive results were obtained except in the case of artificially seeded tanks. The survival of the organisms did not exceed 24 hours for v. Cholerae nor 2 to 3 days for B. typhosus.—*Jack J. Hinman, Jr.*

The General Construction of Colloids. Wo. Pauli. Kolloid-Z, 28: 49–51, 1921. From Chem. Abst., 16: 182, January 20, 1922. Formulas are given for some colloidal hydrosols, including $Al(OH)_3 \cdot Al(OH)_2 \cdot Cl$, in which the colloidal ion may be either positive or negative.—*R. E. Thompson.*

The Effect of Freezing on Colloidal Selenium. A. Gutbier and F. Flury. Tech. Hochschule Stuttgart. Kolloid-Z., 29: 161–72, 1921. From Chem. Absts. 16: 182, January 20, 1922. The coagulation of colloids by freezing was studied, selenium hydrosols being used in the experiments. Secondary sols, less stable than the original preparation, are obtained on freezing and remelting. If the primary sol is dialyzed the stability of the secondary sols obtained varies inversely with the length of time dialysis, until finally complete coagulation results on freezing. The sols are more sensitive to freezing the greater the concentration of the colloid.—*R. E. Thompson.*

Thickness of Stratified Films. P. V. Wells. Ann. Phys., 16: 69–110, 1921. From Chem. Abst., 16: 185, January 20, 1922. The author, in studying the thickness of soap bubble films, confirmed Perrin's statement that "The (colored) regions of the films are formed by the superposition of a number of identical elementary leaflets." The thickness of the elementary leaflet is the same as the thickness of the black spot and is considered to be about 4.4 millimicrons. Both the spot and the leaflet are considered to be bimolecular layers of oleic acid.—*R. E. Thompson.*

American Research Chemicals. C. J. West. National Research Council, Reprint and Circ. Series 23, 28 pp., 1921. From Chem. Abst., 16: 195–6, January 20, 1922. Lists are given of the manufacturers of research chemicals, biological stains and indicators, and H-ion indicators.—*R. E. Thompson.*

Chlorination and the Formation of Chloramines by Means of Nitrogen Trichloride. G. H. Coleman with W. A. Noyes. J. Amer. Chem. Soc., 43: 2211–7, 1921. From Chem. Abst., 16: 244, January 20, 1922. The chlorination of benzene, toluene, benzyl chloride and ethyl chloride by means of nitrogen trichloride was investigated. Equations are given explaining the results obtained.—*R. E. Thompson.*

Automatic Recording and Analytical Apparatus. L. Levy. Chem. Age (London) 5: 652–5. 1921. From Chem. Abst., 16: 513, February 20, 1922. A brief description of recording thermometers and pressure gages, total quantity meters, carbon dioxide recorders, etc., is given.—*R. E. Thompson.*

Boiler Water Treatment Plant. R. June. Blast Furnace and Steel Plant. 9: 670–2, 1921. From Chem. Abst., 16: 454, February 10, 1922. The relative advantages of zeolitic water softeners are discussed. Permutite is classed as a slow-acting and Borromite as a rapid-rate softener, both systems furnishing water of zero hardness. Distilling plants and evaporators, both "single" and "multiple" effects, are sucessfully used in many power plants. The operating results of a Griscom Russell installation are given.—*R. E. Thompson.*

Procter-Wilson Theory as a Working Tool. Its Application to Sewage Disposal. J. A. Wilson. J. Soc. Leather Trades Chem., 5: 268–73, 1921. From Chem. Abst., 16: 454, February 10, 1922. The Procter-Wilson theory of the swelling of protein jellies has been applied to the filtration of Milwaukee sludge. The rate of filtration was shown to be a function of the pH value, and was increased 300 per cent at the optimum value of 3.2. By adding aluminium sulphate and adjusting the pH to 4.3 an increase of 700 per cent was obtained. A complete bibliography is given.—*R. E. Thompson.*

Progress in Cement Making. L. Malphettes. Rev. mat. Constr. trav. pub. No. 140, 81–4, 1921. From Chem. Abst., 16: 623, February 20, 1922. An outline is given of the manufacture of three new types of cement, namely: (1) fused cement, (2) hydraulic lime converted to clinkers by heating in a rotary kiln, and (3) schist cements. Le Chatelier's formula for the formation of $SiO_2 \cdot 3\,CaO$ in artificial cements does not apply to fused cement. Bied states that the latter contains $SiO_2 \cdot 2CaO$ and $Al_2O_3 \cdot CaO$.—*R. E. Thompson.*

The Action of Sodium Carbonate on Chrome Alum Solutions Aged at Constant Temperature. L. Meunier and P. Caste. Le Cuir, 10, 290–2, 1921. From Chem. Abst., 16: 357, January 20, 1922. The amount of sodium carbonate required to start precipitation in chrome alum solutions allowed to stand at constant temperature in diffused light was found to increase to a maximum in

a period of a few hours to days, then slowly decrease to a minimum in a period of weeks or months. It is concluded that chromium sulphate hydrolyses, the chromium hydroxide being first peptized by the normal sulphate with which it slowly forms a less ionized complex. Hydrolysis proceeds further, increasing the ionization and conductivity, and lessening the peptization of the chromium hydroxide. The former reaction predominates first, causing the amount of sodium carbonate required to increase, until the increasing effect of the secon reaction causes it to reach a maximum and subsequently decrease.—*R. E. Thompson.*

Quick Hardening Cement Developed by the French. E. C. Eckel. Eng. News-Record, **87**: 566–7. 1921. From Chem. Abst., **16**: 325, January 20, 1922. A quick hardening, fused cement, consisting of lime 50 per cent alumina 40 per cent and silica etc., 10 per cent is discussed by the author. Test specimens 24 hours old show strengths comparable with 28-day portland cement specimens. In laboratory experiments cubes of this cement have been exposed to (1) sea water (2) saturated calcium sulphate solution and (3) 1.2 per cent magnesium sulphate solution, for nine years and are still intact. This is a remarkable feature as, until the introduction of fused cement, it was generally considered that the disintegration of portland cement in sea water was due to to its alumina content.—*R. E. Thompson.*

Waterproofing Concrete. J. H. Burgess. Commonwealth Eng. (Melbourne) 8, 248–50, 278–82, 306–7, 1921. From Chem. Abst., **16**: 325–6, January 20, 1922. Conclusions are given based on the results of tests made for the permeability of concrete; the pore-filler used being a fine blue metal dust, which acts as puzzolana and fixes the lime. Low permeability and increased strength are obtained by use of fine cement, owing to its greater covering capacity and also to a larger percentage being chemically acted on by the water. Surface area of the particles in all concretes is very important especially in lean mixtures. Blue metal dust increased the impermeability and the strength of mortars of all ages and of concrete at ages of 6 to 12 months. The amount used should be in the proportion of 1 part of blue metal dust to 2 parts of cement.—*R. E. Thompson.*

Progress in Investigation of Alkali Action on Concrete. E. C. Bebb. Eng. World, **18**: 391–4, 1921. From Chem. Abst., **16**: 326, January 20, 1922. The conclusions drawn from field tests conducted by a committee consisting of representatives of the United States government Bureaus and of the Portland Cement Association: (1) Hand-made tile of quaking or mushy consistency, and tile made on a tamping machine, give the best results. (2) The action of alkali sulphates is more severe than that of chlorides or carbonates (3) Lean mixtures are more seriously and rapidly affected than rich mixtures. (4) On the basis of the percentage of total solids in waters containing sulphates, disintegration of the poorer grades of concrete begins at 0.2 per cent and increases with the concentration up to 2 to 3 per cent, at which concentration even the best concretes disintegrate rapidly. (5) Durability appears to be dependent upon impermeability, which is determined by the richness of the mixture and gradation of aggregates.—*R. E. Thompson.*

The Basicity of Chromium Salts and its Graphical Representation. Georg Grasser. Collegium, 319–25, 1921. From Chem. Abst., **16**: 357, January 20, 1922. In the reaction of a soluble chromium salt with sodium carbonate a series of basic compounds is obtained. The limiting compounds, i.e., chromium sulphate and chromium hydroxide, represent an increase in basicity from 0 to 100 per cent. A graphical method of denoting the basicity of intermediate compounds is described which may be applied generally to basic compounds.—*R. E. Thompson.*

Specification for Petroleum Products. Bureau of Mines Technical Paper 305. Specifications adopted by the Interdepartmental Petroleum Committee, effective January 23, 1922 and amended March 1, 1922, for the use of the various departments and independent establishments of the United States government. They supersede the specifications published in Bulletins 1 to 5, inclusive, of the Committee on Standardization of Petroleum Specifications. The products covered are gasoline, napthas, burning oils, fuel oils, and lubricants.—Geo. C. Bunker.

How to Make Forms for Concrete Buildings. Beams & Girders. W. F. Lockhardt. Concrete, **20**: 191, May, 1922. The fourth article of a practical series written for builders.—*Geo. C. Bunker.*

Measuring Area of Indicator Diagram. Power, **55**: 693, May 2, 1922. Explains the use of the planimeter for obtaining the mean effective pressure. Illustrated.—*Geo. C. Bunker.*

An Electrically Operated CO_2 Recorder. W. G. Webster. Power, **55**: 691, May 2, 1922. Consists of a Wheatstone-Bridge with an indicating or recording galvanometer, calibrated in per cent CO_2, a soot filter, and a storage battery. Illustrated.—*Geo. C. Bunker.*

Finding the Developed Horsepower of an Engine. Power, **55**: 735, May 9; 822, May 23, 1922. These articles deal with the process of computing the indicated horsepower. A table of horsepower per pound of mean effective pressure is included in the second article.—*Geo. C. Bunker.*

Water Returns to Steam Heating Boilers. Power, **55**: 746, May 9, 1922. Abstract of the report of the Steam Boiler and Flywheel Service Bureau which is composed of the engineering heads of all the companies doing a boiler insurance business.—Geo. C. Bunker.

Putting Steam Turbines in Service. Power, **55**: 756, May 16, 1922. As the sizes of steam turbines increase, the problem of warming a unit up and putting it in service has become more serious. The starting of single-cylinder, tandem-compound and cross-compound two-and-three-cylinder machines is considered. Illustrated.—Geo. C. Bunker.

A Meter for Recording Alkalinity of Boiler-Feed Water. R. C. Arthur and E. A. Keeler. Power, **55**: 768, May 16, 1922. The installation described

was conducted by the Leeds & Northrup Co. in co-operation with the Public Service Electric Company of New Jersey, at the Perth Amboy plant of the latter company. A new combined electrode, developed to take the place of the calomel and hydrogen electrodes, is immersed in a small bypassed flow of the feed water and recording potentiometer is used to record the voltage existing across the electrodes. The wide range of voltage for small changes in the hydrogen-ion concentration of the feed water makes the meter very sensitive to small changes in the quality of the feed water. The advantage of the acidity recorder lies in the convenience with which automatic control of alkalinity can be secured. By a simple system of relays and contacts a motor-operated valve can be made to control automatically the additions of an alkaline solution to the boiler-feed water. Such an equipment has been installed and the authors express the hope that data on its performance will soon be available for publication.—Geo. C. Bunker.

Corrosion Due to Galvanic Effect. M. H. T. Crisp. Power, 55: 788, May 16, 1922. On two occasions, once in South Africa and once in India, the author found that wrought-iron pipe lines, half-buried in the ground, were being corroded on the inside and along the top at regular spacings of about 18 inches. Eventually jets of water appeared through some of the spots weakened by the corrosion. Burying the pipe-lines stopped the corrosion. The author believes that thermocouples existed due to the variation in temperature between the hot and cold portions of the pipe. The hot portion of the exposed pipe acted as the anode and the cooler portion as the cathode, with the water as the electrolyte, with the results that galvanic action developed.—Geo. C. Bunker.

The Colorimetric Method of Determining Hydrogen Ion Concentration. Water & Water Eng. (London), **24**: 131, April 20, 1922. An elementary discussion.—Geo. C. Bunker.

The Price of Gas, Electricity, Water, etc., Before and After the War (in Germany.) Permien. Gas-und Wasserfach, **65**: 83–85, 1922. The price of water in Germany is from 6 to 10 times the pre-war price.—*Jack J. Hinman, Jr., (MF) (Courtesy Chem. Abst.)*

The Permissible Salt Concentration in Drinking Water. H. Stoof. Gas- und Wasserfach, **65**: 59, 1922. The water of the Elbe and the Weser should not have its salt concentration raised above 250 to 350 parts per million by industrial wastes. Salt and potash plants should be required to treat at least a part of their wastes before discharging. References.—*Jack J. Hinman, Jr., (MF) (Courtesy Chem. Abst.)*

The Corrosion of Metal Conduits. Hugo Kühl. Gas-und Wasserfach, **65**: 99–102, 1922. A review of literature dealing with the corrosion of pipes and the prevention of trouble. Lead, copper, zinc, cast iron, and alloy pipes are considered.—*Jack J. Hinman, Jr., (MF.) (Courtesy Chem. Abst.)*

On Water Losses. M. Engelman. Gas-und Wasserfach, **65**: 115–117, 1922. cf. J. Gasbeleutung., **63**: 528 and 660, 1920. An attempt to explain losses of water at Bielefeld, Germany. Loss through taps and appliances, leaks in piping system, incorrect metering, etc. amounted to 9.2 per cent. Loss not accounted for amounted to 9.7 per cent. The meters used did not register at rates less than 28 liters per hour (7.5-gallons per hour) and hence did not record part of the water lost through small leaks.—*Jack J. Hinman. Jr.*, (*MF.*) (*Courtesy Chem. Abst.*)

Bacteria Fermenting Lactose and Their Significance in Water Analysis. Max Levine. Iowa State College of Agriculture and Mechanical Arts Official Publication, 20: 31, 1921. A Bulletin of 127 pages in which the author reviews and brings together material from various sources, including his own published papers, grouped under the following topics: (1) Characteristics of the Colon Group of Bacteria. (2) Evidence of two Subdivisions in the Colon Group and tests for their Differentiation. The gas ratio, Voges Proskauer, methyl red, and uric acid tests are strikingly correlated. The members of the colon group which produce acetyl methyl carbinol, are capable of using the nitrogen from the purin ring of uric acid, give an alkaline reaction with the methyl red test, and in the decomposition of glucose, yield a relatively small quantity of acid and two or more times as much CO_2 as H_2. On the other hand, the organisms, which do not produce acetyl methyl carbinol, can not utilize the nitrogen from the purin ring, give an acid reaction with methyl red, break down glucose with the production of a relatively large amount of acid and liberate CO_2 and H_2 is approximately equal volumes. The colon group therefore includes two distinct subdivisions which are characteristically of different sources. These have been designated the coli and aerogenes sections. Their characteristics are tabulated below.

Table XIV. Differentiation of the main subdivisions of the colon group

SECTION	GAS RATIO CO_2/H_2	M. R. TEST	V. P. TEST	GROWTH URIC ACID MEDIUM	HABITAT
Coli	1.0 (Low ratio)	Acid	Neg.	Negative (No growth)	Predominates in feces and sewage
Aerogenes	1.5 or more (High ratio)	Alk.	Pos.	Positive (Good growth)	Predominates in soil and on grains

(3) Classifications of the Colon Group of Bacteria. (4) The Detection of the Colon Group in Water. (5) The Colon Group as an Index of Pollution. The colon group appears to be a convenient and desirable index. The presence of Bact. aerogenes alone in a supply may indicate merely remote pollution or soil contamination which is not objectionable or dangerous. Differentiation of coli and aerogenes in routine work is desirable because it may assist in the detection of the source or nature of the contamination. (6) The Spore Forming Lactose Fermenters and Their Significance in Water Analysis. Appendix A covers routine methods of water analysis and the Colon index. Appendix B is devoted to preparation of Culture media. The bulletin covers well the field of water bacteriology.—*H. L. Long* (*Courtesy A. M. Buswell*).

A Source of Lead Contamination of Cistern Water. Leonard Greenburg. Public Health Reports, 37:30, 1825, July 28, 1922. Report on lead contamination of drinking water in a cistern at U. S. Fish Hatchery station, Ten Pound Island, Gloucester, Mass. The lead flashing, on the roof of the building, was held responsible for the contamination, after experiments had eliminated lead pipe and lead paint.—*A. W. Blohm.*

Correction: On p. 682, July, 1922, Abstracts section, read line 30: "Residual alum is found in the mechanically filtered water in colloidal form, which produces *no* after precipitation."—*Ed.*